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Understanding the impact of a low carbon transition on Colombia

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The analysis underpinning the report is the result of a close collaboration with a brilliant and challenging partner in the Centro Regional de Finanzas Sostenibles (CFS) at Universidad de Los Andes, based in Bogotá and led by Clemente del Valle. Clemente's wealth of experience in Colombian and international public institutions made him the ideal person to partner with for this project. Without his unique combination of expertise in infrastructure sectors, technical rigour across the financial industry and economy policy making, and political acumen, this report might never have seen the light of day.

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Finally, this project has been a group effort within WTW, first conceived of nearly four years ago, following an invite from then Banco de la República board member Jose Antonio Ocampo and Clemente del Valle to David Nelson and Matthew Huxham (then of Climate Policy Initiative Energy Finance) to participate in a workshop on climate risk in Bogotá. As well as a core team of Matthew Huxham, Muhammed Anwar and Alejandro Navas, critical supporting roles have been played by Maria Kamenz, Eoin Strutt, Himanshu Baghel, Joshua Palmer, Riya Devaya, Ali Berjawi, Moiz Bohra, Will Scargill, Benton Suddell, Alex Jones, and Jaime Lezama. David Nelson, Thomas Heller, and Paula Pagniez provided important senior guidance and support. Other WTW colleagues from the region, including Latin America head Hector Martínez, Colombia Head Margarita López and Colombia Head of Consulting Juan Felipe Munera, ensured that this work reflects local realities, making it relevant for WTW's clients.We are also very grateful to Mark Brewster for his work designing this report and to WTW's communication and marketing teams, led by Sebastian Bonillas, Jocelyn Pereyra and Andy Collis for their advice on key messaging.

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Glossary

This report includes several technical terms drawn from economics and finance, which may not be familiar to readers with limited experience in these sectors. This glossary provides "plain English" definition of some of those key terms.

Term	Explanation
Conference of the Parties (COP)	Annual climate change conference organised by the United Nations agency that guides global climate action.
Paris Agreement	International agreement between countries, governing future action with the aim to reduce global warming. Signed after the COP21 conference in Paris in 2015. The Paris Agreement contains a series of rules governing issues, including country climate pledges
Well Below Two Degrees	The global warming goal set out in the Paris Agreement and designed to ensure that runaway climate change is avoided. The target is expressed as an average amount of global warming, compared with pre-industrial levels. "Well below two degrees" was a compromise text, with many parties pushing to limit global warming to no more than 1.5 degrees.
Net Zero	A target for a future state of deep decarbonisation, at a point where countries or companies either emit zero greenhouse gas emissions on a "gross" basis or a "net" basis, after accounting for carbon sequestration that removes carbon from the atmosphere
Risk	In this study, the term is used in its economic or financial sense to mean the potential change in value (up or down) of an asset (financial, economic, or social), given a source of uncertainty (for example, about the speed of global decarbonisation
Climate Transition Risk	Risk arising from accelerated deep decarbonisation
Physical Climate Risk	Risk arising from the physical consequences of global warming
External Transition Risk	For any country, climate transition risk that is not driven by that country's policies
Domestic Transition Risk	Climate transition risk driven by a country's policies
Climate Transition Value at Risk (CTVaR)	For any financial asset, the amount of climate transition risk which is not currently accounted for by financial markets
Net Present Value	A method of valuation used in finance that recognises that cash flows of a given amount received today are worth more than the same amount received in the future, because they are more certain and can be invested
Thermal Coal	Coal that is used mostly in combustion in power stations Coal that is used mostly in combustion in power stations and a range of other industrial processes
Metallurgical Coal	Coal that is used mostly in metallurgical contexts (particularly, in making steel)
Green Hydrogen	Hydrogen made via electrolysis of water, using renewable energy
Blue Hydrogen	Hydrogen made from natural gas, using steam methane reforming, with CO2 emission captured and stored
Carbon Capture, Use, And Storage (CCUS)	Refers to a range of technologies for capturing CO2 generated and preventing it from being leaked to the atmosphere. CCS chains that permanently store CO2 achieve that objective. Carbon capture and use (CCU) technologies, such as those where CO2 is trapped in new materials or recycled in oil and gas extraction options, often only delay emissions to the atmosphere.

Understanding the impact of a low carbon transition on Colombia: At A Glance

1. Colombia's current economic model is highly dependent on the rents from the extraction of coal, oil, and gas. In 2020, 55% of exports came from these sectors. Colombia therefore faces a structural challenge from a Paris-aligned global transition in which demand for these fuels reduces significantly.

2. Colombia is seeking to reach "net zero" by 2050, but economic volatility associated with the decline of the global fossil fuel trade (which Colombia has limited control over) could begin in the coming decade. If Colombian policymakers do not respond proactively to these risks, the country could face lost economic output of more than $88 billion (or 27% of 2019 GDP) between now and 2050.

3. A "business as usual" approach could prove destabilising for the Colombian economy by early in the next decade. A weakening trade balance, falling tax revenues and rising public debt could also contribute to sovereign credit rating downgrades. This would increase the cost of Colombia's climate mitigation and adaptation investments and cost many thousands of jobs.

4. An accelerated transition of Colombia's economic structure (including developing growth sectors with export potential, such as copper) to a low carbon base could help offset some of the decline in "traditional sectors" although the low carbon economic benefits may not accrue over the same timeframes, in the same locations and to the same economic groups as the downsides.

5. In cases where the costs of global and Colombian low carbon transitions could fall on places and economic groups with limited economic resilience (such as mining workers and local governments), Colombia's government should be proactive in providing economic and other support to ease the burden. This support could be funded by a combination of new domestic (fiscal) and international transition-related funding sources.

Executive summary

In November 2021, at the COP26 climate conference in Glasgow, amidst a blizzard of announcements about enhanced climate ambition, the pledges made by the Colombian government helped the country position itself not only as a leader on climate action in Latin America, but globally. Colombia would, in the space of nine years, reduce deforestation – historically the country's largest source of greenhouse gas emissions – to "net zero"[1]. The deforestation pledge was part of a broad-ranging strategy (Estratégia 2050 or "E2050")[2] launched at the summit charting a path for Colombia to reach "net zero" greenhouse gas emissions by 2050. In the months that followed, Colombia continued to release more detail on its low carbon development plans, including roadmaps for hydrogen[3] and offshore wind[4] industries, the issuance of Latin America's first local currency sovereign green bond[5], the launch of a green taxonomy aimed at both private and public spending[6] and a range of new financing arrangements with development partners[7]. These moves are the latest in a series of actions over the last few years aimed at kickstarting (and attractive investment in) accelerated Colombian decarbonisation, particularly in power generation.

Hitherto, Colombia has dedicated much more effort to the promotion of investment in new industries than it has to the question of transition – and ultimately wind-down – of existing industries, such as coal mining, that currently are a significant generator of export revenues, taxes, and jobs. The Petro government's much-debated stances on new oil and gas exploration and maintaining a prohibition on "fracking" may shift this balance, enhancing the perceived importance of managing the transition effectively, both in the public debate and in the deliberations of policymakers, investors, and financial regulators.

A key job of policymakers in the Petro administration focused on climate and transition issues under is to convert Colombia's climate-related "vision" documents (such as the Nationally Determined Contribution[8] , E2050 and CONPES de Transición Energética[9]) into detailed implementation plans that are also coherent with the administration's overarching policy objectives (as set out in the Plan Nacional de Desarollo[10]). Designing a plan for decarbonising Colombia's steel or cement sectors, is not just a question of understanding the relative costs and benefits of different technological options, but a question of understanding the changing nature of the global situation in which Colombia will be implementing its transition (and which ultimately, will influence the relative costs and benefits of different technological options). Colombia's climate "vision" documents to-date seem optimistic about issues such as the long-run competitiveness Colombian coal companies in Asian markets and the potential for unconventional production to enable an upswing in Colombian hydrocarbon production and a return to self-sufficiency. Implicitly, these policies assume that Colombia will be able to meet its long-term goals without significant change to its economic model.

However, Colombia is not facing its transition challenges in a vacuum, rather it is planning a transition in a world where most other countries are pursuing a similar objective, albeit down different paths and at different speeds. The structural changes that will results, including to internationally traded markets in primary commodities, agricultural and industrial goods, will mean that firms operating in those markets are likely to have a different value in a global transition that is aligned with the Paris Agreement goal of keeping global warming to well below two degrees Celsius (WB2C) than that would be the case in a world that doesn't accelerate decarbonisation. This risk – of lower or higher economic, financial, and social value - is what we call "climate transition risk". The risks arising from global and regional trends are what we call "external (climate) transition risk".

A deeper understanding of climate transition risk would be helpful for Colombian policymakers as they seek to be cautious when specifying the speed and shape of Colombia's transition in more detail. Given the risks posed by Colombia's exposure to the global transition (external transition risks that Colombia has limited control over), a slow transition and eventual transformation of Colombia's fossil fuel production and emissions-intensive industries may actually be a very risky choice, with implications for economic and financial stability. By contrast, an accelerated wind-down of carbon-intensive industries that is not matched by an accelerated scale-up of lower carbon industries of appropriate size could also weaken the country's economy and threaten social consent in Colombia's long-term transition goals.

1. Source: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/273337/joint_statement_deforestation_colombian_amazon.pdf
2. Source: https://unfccc.int/sites/default/files/resource/COL_LTS_Nov2021.pdf
3. Source: https://www.minenergia.gov.co/documents/10192/24309272/Hoja+Ruta+Hidrogeno+Colombia_2810.pdf;jsessionid=0NAJdO0gm5QBqOyq47qgr9nL.portal2#:~:text=La%20Hoja%20de%20Ruta%20del,Acuerdo%20de%20Par%C3%ADs%20del%202015
4. Source: https://www.minenergia.gov.co/es/micrositios/enlace-ruta-eolica-offshore/
5. Source: https://www.climatebonds.net/2021/10/colombia-leading-path-green-finance-latin-america
6. Source: https://www.responsible-investor.com/colombia-launches-first-latam-green-taxonomy-excludes-nuclear-and-gas/
7. The agreement with the European Investment Bank signed at COP27 has been one of a number of arrangements designed to ensure sufficient financing for the energy transition (https://www.eib.org/en/press/all/2022-471-eib-at-cop27-eib-and-the-colombian-government-commit-to-supporting-energy-transition). We are not aware of any financing secured to support the sort of transformative action recommended in this report.
8. Source: https://unfccc.int/sites/default/files/NDC/2022-06/NDC%20actualizada%20de%20Colombia.pdf
9. Source: https://colaboracion.dnp.gov.co/CDT/Conpes/Econ%C3%B3micos/4075.pdf
10. Source: https://www.dnp.gov.co/Paginas/plan-nacional-de-desarrollo-2023-2026.aspx

At the same time, a deeper understanding of the structural changes that are the drivers of climate transition risk will also be key to the successful exploitation of the potential benefits of a low carbon transition. In Colombia, there will be opportunities to scale up mining of transition metals, such as copper (and potentially also, nickel and iron), as well as the scaling up of low carbon domestic industries, such as fertiliser and synthetic fuels for aviation and shipping. Internationally, there is growing consensus that lower carbon societies are also ones with lower air pollution and greater economic productivity[11].

However, many Colombian commentators remain concerned that moving away from fossil fuels will damage the country's future economic growth and development potential[12]. A successful series of low carbon transition policies will require a sophisticated and evolving attitude to downside risks and opportunities, a commitment to basing policy decisions on evidence about short- and long-term consequences, a generally proactive approach from policymakers and regulators and a commitment to ensure that downside risk is not placed on those with limited capacity to bear it.

WTW, in partnership with the Centre for Sustainable Finance (CFS) of the Universidad de Los Andes (UniAndes) have, supported by the Agence Française de Développement (AFD), undertaken an analysis of Colombia's climate transition risks (downside) and opportunities (upside) and developed a series of recommendations for how Colombian policymakers, central bankers, financial supervisors, financial institutions and real economy corporates can more effectively incorporate these risks and opportunities into their planning processes.

The project, undertaken in close collaboration with the Departamento Nacional de Planeación (DNP), builds on previous analyses undertaken by organisations like 2 Degrees Investing Initiative (2DII)[13], the World Bank[14] and the International Monetary Fund[15] and ongoing work by the Superintendencia Financiera de Colombia (SFC)[16] and Banco de la República (BanRep)[17], and is designed to provide data as well as insight for ongoing use by policymakers. The analysis was built from microeconomic modelling of value chains and financial modelling of firms in thermal coal, metallurgical coal and coke, oil and gas, power, transport, steel, cement and other industrial sectors and the mapping of the allocation of climate transition risk in the Colombian economic system, via transmission channels, such as ownership, financing structures, royalties, taxes and wages. We considered a range of options for mitigating the potentially destabilising risks highlighted in the paper, including the benefits of potential growth industries and the potential benefits of accelerated decarbonisation in transport and industrial sectors.

In the rest of this Executive Summary, we review the ten key findings and recommendations from the project, also set out in table ES-1 below.

11. Source: https://www.wri.org/insights/low-carbon-growth-26-trillion-opportunity-here-are-4-ways-seize-it
12. Source: https://www.repository.fedesarrollo.org.co/handle/11445/4318
13. Source: https://2degrees-investing.org/wp-content/uploads/2022/03/From-Bogota-to-Paris.pdf
14. Source: https://openknowledge.worldbank.org/bitstream/handle/10986/36586/Not-So-Magical-Realism-A-Climate-Stress-Test-of-the-Colombian-Banking-System.pdf?sequence=1&isAllowed=y
15. Source: https://www.imf.org/en/Publications/WP/Issues/2021/11/05/Climate-Related-Stress-Testing-Transition-Risk-in-Colombia-504344
16. Source: https://www.superfinanciera.gov.co/jsp/10111958
17. Source: https://investiga.banrep.gov.co/es/espe102

Table ES-1: **Summary of key findings and recommendations**

How exposed is Colombia to climate transition risk?
1. Colombia faces material downside risk from the global transition, totalling $88 billion in net present value terms (or 27% of 2019 GDP) between 2022 and 2050. Thermal coal exporters would be worth $43 billion less in a WB2C scenario, compared with a BAU one, with remainder mostly falling on the oil value chain ($41 billion), natural gas and metallurgical coke.
2. Thermal coal exports are likely to be impacted earlier than other sectors. In a WB2C scenario, exports would largely cease by the early-to-mid 2030s. Unless Russian coal exports remain constrained, Colombian coal exports are unlikely to be competitive in the long run in Asian markets because of shipping costs and distance.
3. Declining conventional production of oil and gas could make the Colombia country a net importer of hydrocarbons by the early-to-mid 2030s in both BAU and WB2C scenarios. Recent offshore gas finds could moderate this picture but are subject to major uncertainty around cost and timing.
Who faces Colombia's climate transition risk?
4. Of the firms in impacted sectors, Ecopetrol faces the largest absolute downside through its exposure to oil and gas prices. However, independent oil and gas producers and coal mining companies face a much more severe challenge, with higher amounts of risk relative to market value and for the oil and gas companies, higher leverage. Firms have options to protect themselves via diversification, although coal miners have the least time to make the transition.
5. The risk mitigation actions of firms in a WB2C scenario (including the potential early closure of coal mining) are likely to shift downside risk onto workers, communities, and local governments. As well as putting between 25,000-30,000 direct jobs at risk (and many more indirect jobs), a structural decline in hydrocarbon royalties would create a major challenge for the local government funding system and hence, for the central government, itself. Policies designed to incentivise domestic decarbonisation (such as the redesigned carbon tax) could create more risk to many of the same parties, as well as material broad-based economic and other benefits.
6. The Colombian government could and should provide support for those facing downside risk, but in doing this, it could easily end up with nearly half of the total $88 billion on the public balance sheet. If left unmitigated, this transition risk would put at risk Colombia's sovereign credit rating, creating a series of additional macroeconomic and financial system costs and risks.
What are Colombia's options?
7. To ensure that Colombia's transition is orderly and achieved at the lowest possible costs, policymakers, regulators, and investors should incorporate climate transition risk analysis into decision-making processes.
8. Colombia should continue to take proactive steps to diversify the export basket, including both extractive and non-extractive sectors (such as agricultural products, tourism etc). Colombia potentially has major opportunities in sectors that would grow in a global transition (transition metals and synthetic fuels). However, large scale benefits may not arise early enough to offset climate transition downside risk. Unless Colombia takes the opportunities arising from planned domestic decarbonisation to grow its industrial base, the imports required to implement that strategy could also have impacts on the balance of payments.
9. Accelerating Colombia's domestic transition (and development of a related industrial base), particularly in power, transport, and industry, brings an opportunity to mitigate external climate transition risk, by reducing future imports of oil and gas and helping to incubate hydrogen-related export industries
10. The government should proactively target support for parts of the economy that face climate transition risk but have limited capacity to bear it. Where appropriate, it may be able to draw on sources of fiscal revenue (including additional taxes during periods of high commodity prices) as well as new international sources of funding targeted at these issues

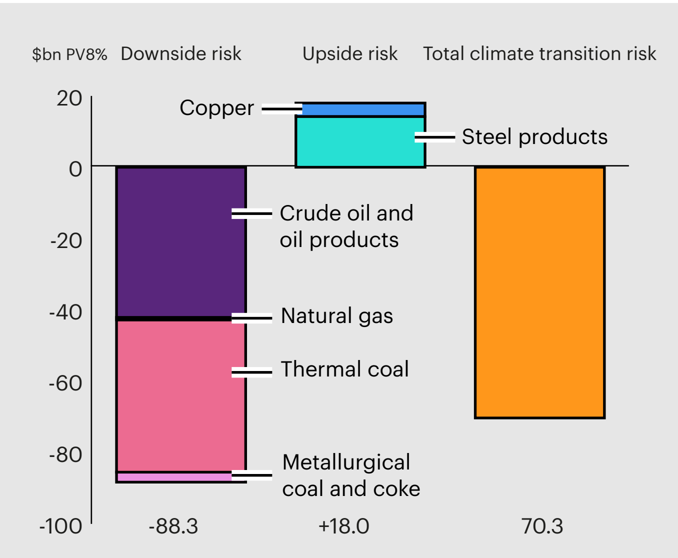
In the rest of the Executive Summary, we provide some further commentary on these findings and recommendations. Further detail on the methodology used to develop the analysis is set out in chapter 2 and the results and arguments supporting those findings and recommendations are set out in Chapters 3 to 5 of this report.

How exposed is Colombia to climate transition risk?

1. Colombia faces material downside risk from the global transition, totalling $88 billion in net present value terms (or 27% of 2019 GDP) between 2022 and 2050. Thermal coal exporters would be worth $43 billion less in a WB2C scenario, compared with a BAU one, with remainder mostly falling on the oil value chain ($41 billion), natural gas and metallurgical coke.

In a global low carbon transition consistent with keeping global warming to "well below two degrees Celsius" (a WB2C scenario), the value of several of Colombia's industries will be lower than in a world with a slower transition and higher global emissions (a BAU scenario). These transition dynamics, caused largely by the decarbonisation activities of companies and countries outside of Colombia, will reduce global demand and prices (both exports and some domestic prices) for thermal coal, crude oil and oil products, natural gas and metallurgical coke, sectors, which, together, made up 55% of Colombia's exports in 2019.

Figure ES-1: **Colombia's external climate transition risk by real economy sector**[18]



We measure the size of this risk as the difference in the net present value of cash flows for each sector between 2022 and 2050 between a WB2C scenario and a BAU scenario. The total $88 billion represents economic value to Colombia that would not materialise in a WB2C and is large in the context of the country's economy (at 27% of 2019 GDP). As illustrated in figure ES-1, this risk arises principally in thermal coal exports and the oil value chain.

With differing dynamics and timings driving global transitions across these sectors, Colombia would not need to face the full $88 billion risk in one year. However, if Colombian policymakers were not to pay attention to these risks and the country were to continue with its current trajectory, the impact on Colombia of a successful global transition in line with the Paris Agreement would be weaker economic outputs, employment and tax revenues than expected today.

By contrast, if the world were not to meet Paris Agreement goals, global warming (and associated physical damage, lost productivity and other negative impacts) would be higher and climate transition risk of the sort described in this paper would be lower. In either case, continuing the current trajectory appears a risky strategy.

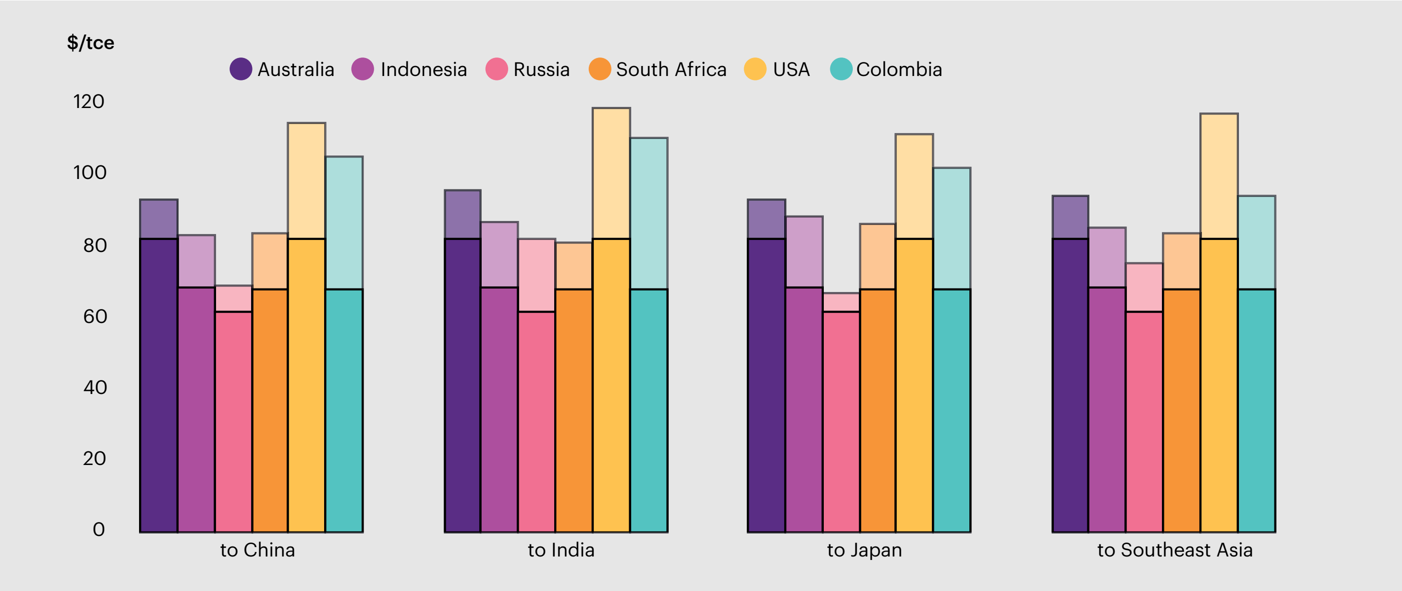
2. Thermal coal exports are likely to be impacted earlier than other sectors. In a WB2C scenario, exports would largely cease by the early-to-mid 2030s. Unless Russian coal exports remain constrained, Colombian coal exports are unlikely to be competitive in the long run in Asian markets because of shipping costs and distance.

Thermal coal exports are likely to be impacted by the global transition earlier than other sectors. As the costs of wind and solar generation fall, countries around the world are increasingly turning away from coal as a source of new power generation capacity. This, combined with the pullback of global financial markets from coal mining and coal power plant investments, means that demand for thermal coal traded internationally has likely already peaked.

Before the recent sharp increase in coal prices following the start of the war in Ukraine, Colombian coal mining companies were targeting a pivot to Asian markets as a potential source of growth or at least, a more resilient source of demand in a global transition. However, our analysis shows that, because of higher shipping costs, Colombian coal (despite its relatively high quality) would be less competitive in Asian markets than coal than most of its competitors.

18. Source: WTW and UniAndes analysis. See chapter 3 for more detail

Figure ES-2: **Colombian coal costs for delivery in Asian markets in 2025, compared with competitors[19] (Mining costs are in a darker shade and shipping costs in a lighter shade)[20]**



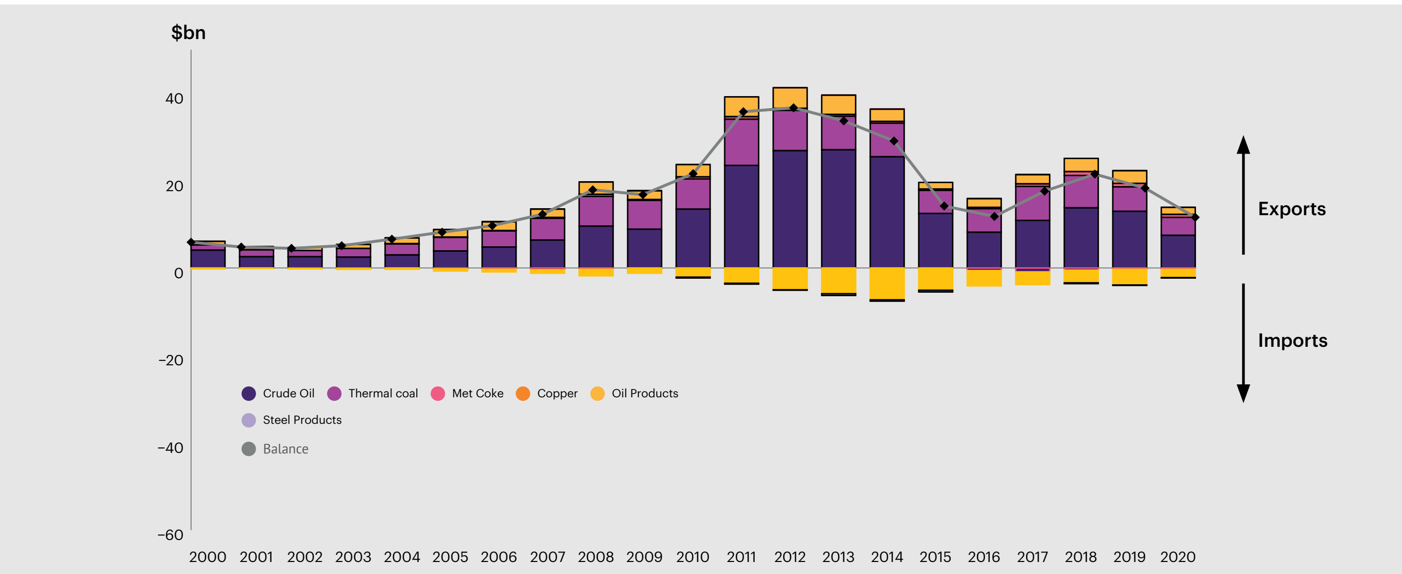
In a WB2C scenario, Colombian exports would become increasingly uncompetitive, with volumes reducing before exports largely cease in the first half of the 2030s. If Russian coal exports, affected in 2022 by a G7 embargo and infrastructure constraints, were to be limited over the long term, this may create space for a slightly more gradual wind-down of the Colombian export coal industry.

However, our analysis showed that major new investments in the industry – in coal mines or infrastructure – would likely be loss-making in a WB2C scenario. This is also likely to be case given for coal mines targeting domestic demand, after the extension of the carbon tax to include thermal coal[21] .

3. Declining conventional production of oil and gas could make the Colombia country a net importer of hydrocarbons by the early-to-mid 2030s in both BAU and WB2C scenarios. Recent offshore gas finds could change this picture, but are subject to major uncertainty around cost and timing.

The idea of a Colombia without economic reliance on fossil fuel exports may seem hard to believe, given the level of reliance on those sectors in recent years. In the years since 2000, Colombia has recorded a cumulative net trade surplus in fossil fuels of $336 billion and a cumulative net trade deficit in all other goods of $378 billion. Figure ES-3 shows how the combined fossil fuel trade balance (with the net position represented by the grey line) was in surplus every year from 2000 to 2020.

Figure ES-3: **Colombia's historic trade balance from fossil fuels (compared with a deficit in trade in other goods, in all years)[22]**



19. Analysis based on WTW in-house global thermal coal model
20. Source: WTW and UniAndes analysis. See chapter 3 for more detail
21. The extension of the scope of the carbon tax to cover thermal coal was included in the large-scale tax reform passed in November 2022. Full exposure to the tax will be phased in over four years. Source: https://www.minhacienda.gov.co/webcenter/ShowProperty?nodeId=%2FConexionContent%2FWCC_CLUSTER-200757%2F%2FidcPrimaryFile&revision=latestreleased
22. WTW and UniAndes graphic, based on information from DANE

However, our analysis shows that this picture is due to change, whether or not the world accelerates decarbonisation (figure ES-4 shows the BAU scenario and figure ES-5 shows the WB2C scenario). Based on data from energy consultancy Rystad Energy and the authors' climate transition analysis, Colombia stands to become a net importer of oil and gas by the mid-2030s, unless major new sources of oil and gas production are pursued and/or Colombia takes action to reduce its growth in demand for those commodities (including through accelerating domestic decarbonisation). Our analysis of public information about recent offshore gas deposits shows that, while they are more likely to have an impact in the 2030s than the 2020s, they could reduce Colombia's future gas imports compared with our scenarios, but not to such a degree that it would affect the structural change described above.

These dynamics, if left unmitigated, could cause macroeconomic stresses (including depreciation of the peso) and could fundamentally change Colombia's economic relationship to global fossil fuel prices. However, the rest of the findings set out why and how the authors believe that such a transition is possible, provided that the government is proactive.

Figure ES-4: **Colombia's future trade balance from transition-exposed sectors (BAU)**[23]

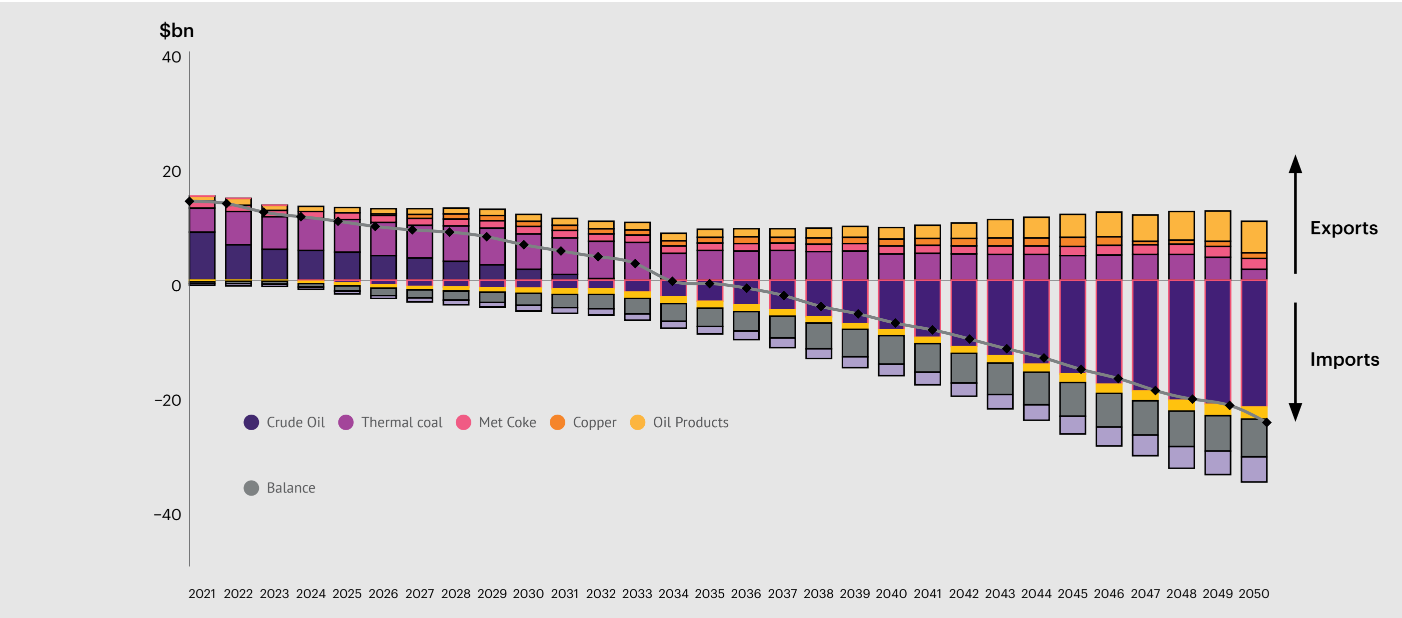
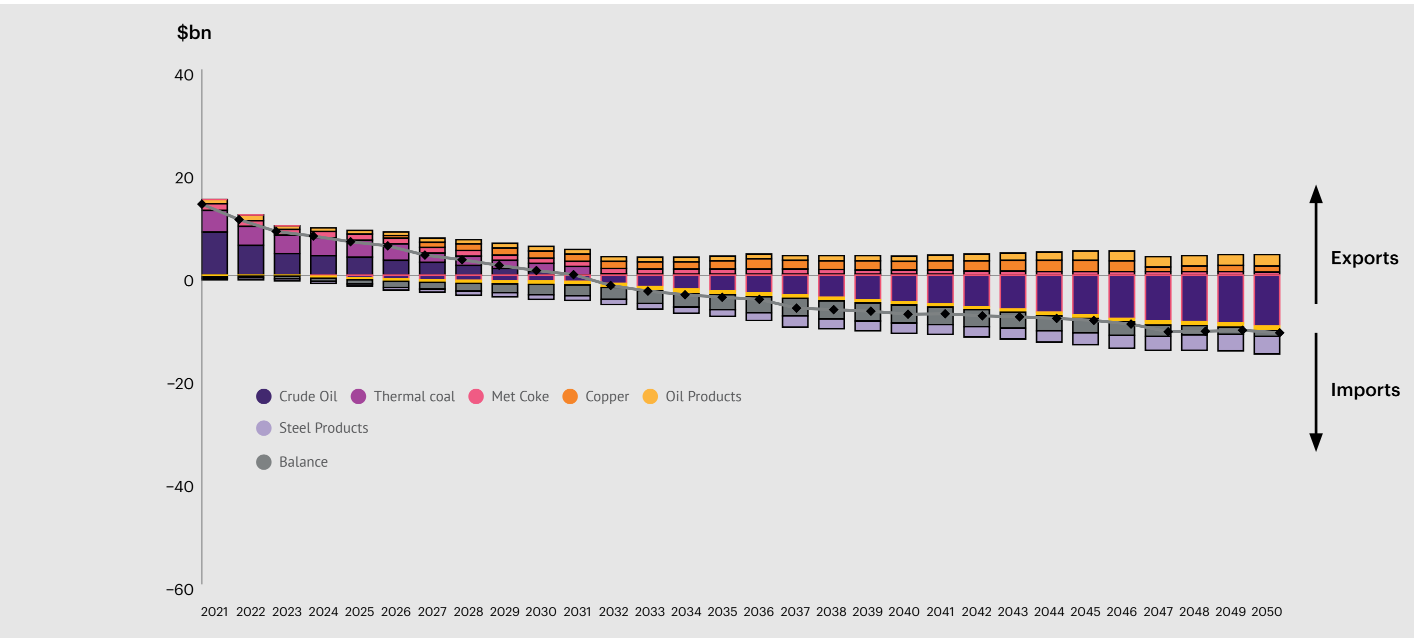


Figure ES-5: **Colombia's future trade balance from transition-exposed sectors (WB2C)**[24]



23. Source: WTW and UniAndes analysis. For more detail, see chapter 3.
24. Source: WTW and UniAndes analysis. For more detail, see chapter 3.

Who faces Colombia's climate transition risk?

4. Of the firms in impacted sectors, Ecopetrol faces the largest absolute downside through its exposure to oil and gas prices. However, independent oil and gas producers and coal mining companies face a much more severe challenge, with higher amounts of risk relative to market value and for the oil and gas companies, higher leverage. Firms have options to protect themselves via diversification, although coal miners have the least time to make the transition.

Firms in the affected sectors are the ones that initially bear external transition risk, through the impact of the global transition on their sales volumes, prices, and costs. Despite its recent strategic moves to diversify from fossil fuels and pilots in green hydrogen, Ecopetrol's dominance of the oil and gas sector means that it is the firm that has the largest absolute downside exposure (see the horizontal axis of figure ES-6), at $13.2 billion, though at only around 20% of enterprise value (see the vertical axis of figure ES-6), this compares very favourably with its large integrated international peers, according to in-house WTW research.

By contrast, thermal coal exporters and oil-focused independent exploration and production companies face climate transition risk exposure that is so high (at 70-90% of their current size), that they might face financial challenges should the risk crystallise before they diversify their portfolios. Particularly at risk are coal mining companies (highlighted in yellow in the figure below), given the fact that transition impacts are likely to materialise earlier, although independent oil companies, such as Frontera Energy Corporation and GeoPark Limited have higher leverage and near-term refinancing requirements, which limited their financial flexibility.

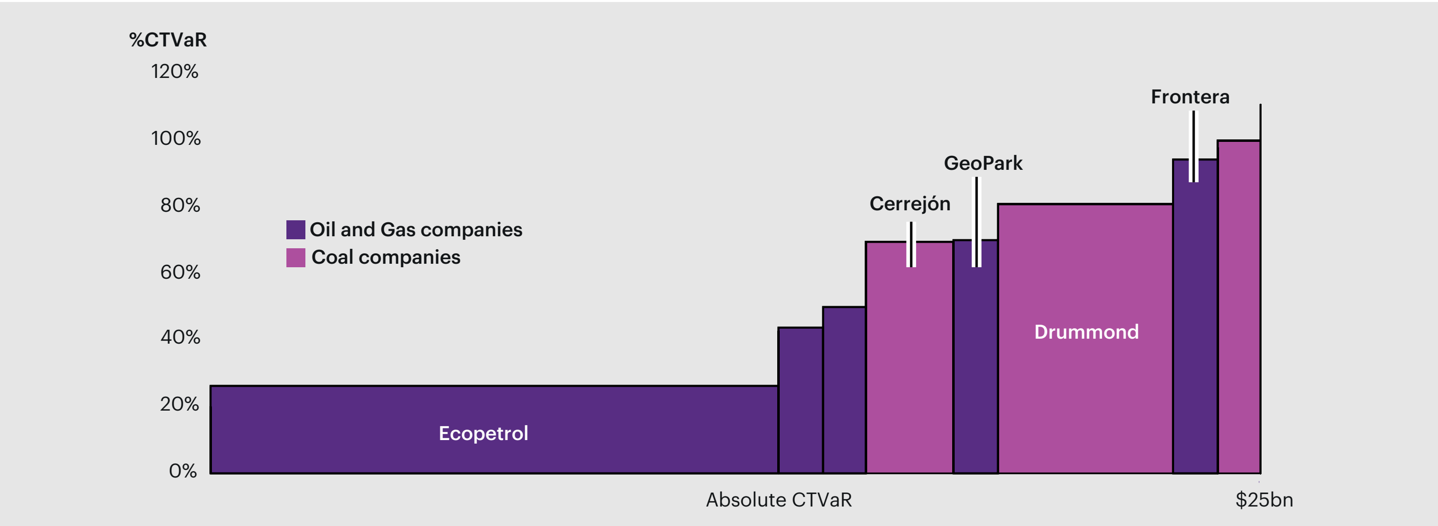
As coal exporting companies and oil and gas production companies are mostly financed in international capital markets, the direct exposure to these risks of the Colombian financial sector should be manageable[26] although the indirect exposure through their holdings of Colombian sovereign debt (see recommendation 6) could be much more serious.

5. The risk mitigation actions of firms in a WB2C scenario (including the potential early closure of coal mining) are likely to shift downside risk onto workers, communities, and local governments. As well as putting between 25,000-30,000 direct jobs at risk, a structural decline in hydrocarbon royalties would create a major challenge for the local government funding system.

The impact of a global transition would be to make several strategic Colombian resource and industrial assets persistently loss-making. If the firms that currently own those assets were to seek to close those assets to stem their losses, it would have serious knock-on impacts for adjacent industries and regions.

Our analysis showed that, in a WB2C scenario, nearly 20,000 direct jobs (and significantly more indirect jobs) could be at risk in thermal coal mining in La Guajira and Cesar in the next ten years, with potential knock-on impacts for the broader viability of the Fenoco rail line and ports at Santa Marta, Puerto Nuevo and Puerto Brisa, all of which are currently very reliant on transport of coal. Coal miners in Norte de Santander, Cundinamarca, Boyacá and elsewhere in the interior of the country have similar employment numbers, but these regions will be more resilient (in terms of both job losses and overall risk) to these trends due their relative insulation from global markets. While they will face downside risk

Figure ES-6: **Climate transition risk across key companies in coal and oil and gas sectors**[25]



25. Source: WTW and UniAndes analysis. For more detail, see chapter 4.
26. We understand anecdotally that the Colombian financial sector has greater loan exposure to the broader oil and gas value chain. While this study considers exploration, production, refineries, and pipelines in detail, we have not conducted a detailed analysis of the supply chain to those primary industries.

from Colombia's decarbonisation plans, the Colombian government has more control over the timing and planning for this transition.

Away from coal, several other Colombian industrial assets will face longer-term challenges the global transition, in particular, the Barrancabermeja refinery whose profitability would gradually be eroded as the refinery needs to switch to more expensive, imported crude.

Declining volumes and early closure and mining, oil, gas, and industrial assets would not only create a challenge for employment and local economic activity, but also for the funding of local governments, who rely on royalties (regalías) and directly levied taxes (ICAs) for a significant amount of their budgets. In 2019-20, Arauca, Casanare, Cesar, Córdoba, La Guajira, and Meta departments all relied on royalties for between 10-15% of their total revenues, while declines in ICA taxes would be particularly damaging for Santander department and municipalities such as Barrancabermeja. A structural decline in those revenues that could result from a global transition would put at risk the sustainability of the system of funding Colombian public services. Colombian policymakers should also consider the impact of domestic decarbonisation decisions on the sustainability of local government funding, since this will impact some of the same revenue sources (ICA) as those impacted by the global transition as well as other revenues (including several taxes relating to liquid fuel sales) not affected by the global transition.

6. The Colombian government could and should provide support for those facing downside risk, but in doing this, it could end up with nearly half of the total $88 billion on the public balance sheet. If left unmitigated, this transition risk could put at risk Colombia's sovereign credit rating, creating a series of additional macroeconomic and financial system costs and risks.

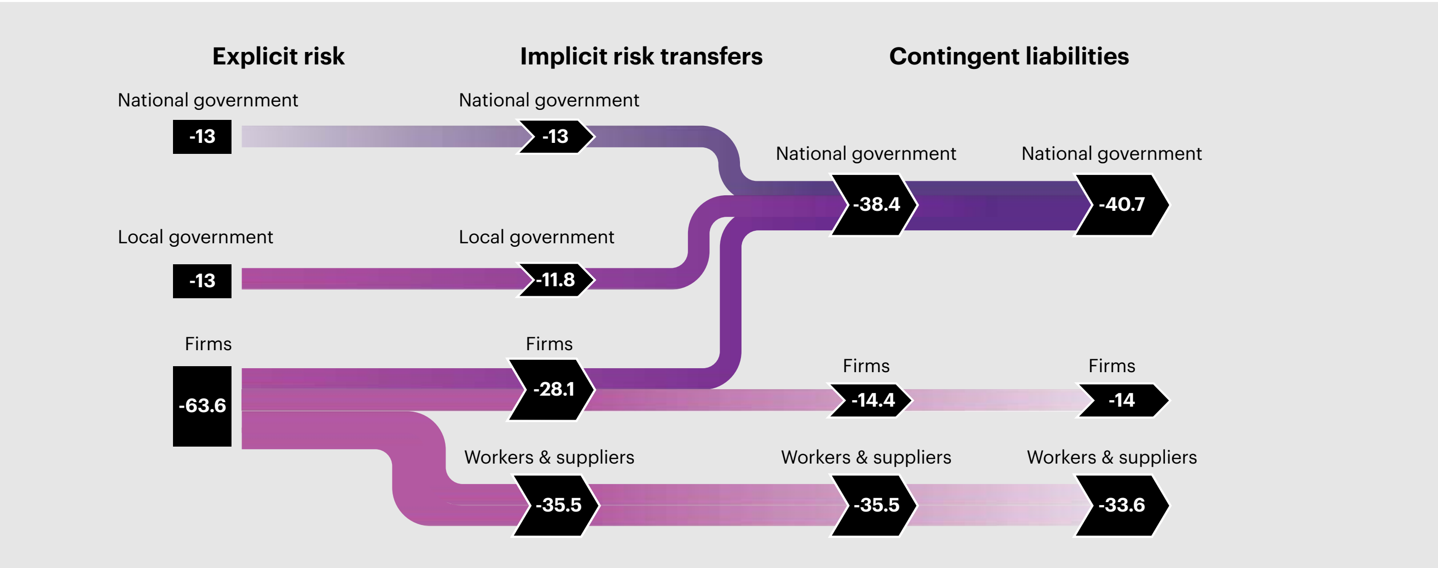
While climate transition risk initially lies principally with Colombian firms, the national government is also directly exposed to these risks through the taxes that it receipts on those firms' profits and through the value of its investment in Ecopetrol. The exposure would be between $25-30 billion between 2022-2050.

However, in practice, national government exposure could end up being much higher than that, if it takes action to protects local governments, workers, and communities to protect them against risk that they have little capacity to bear. If national government were to undertake to make additional transfers to compensate workers and local governments for the payments that they would not receive, central government could end up bearing closer to half of the $88 billion. This is even before accounting for material additional potential costs to support or "bail out" private sector enterprises. These risk transfers are illustrated in figure ES-7.

National government climate transition risk of more than $40 billion (as in figure ES-7) represents 12% of 2019 GDP. Additional impacts not quantified in this study would arise from the broader macroeconomic impact of declining output in coal and hydrocarbon sectors, impacting demand particularly in areas where the industries are based. A declining trade balance could also result in a depreciation of the peso, a rise in the value of foreign currency denominated debt, the peso prices of imported goods and potentially, increases in interest rates. These could create a macroeconomic drag that would increase the cost of future investment, including in domestic decarbonisation.

With much of this risk likely to be concentrated in the late 2020s and early 2030s, these risks, if left unmanaged, could pose a threat to Colombia's sovereign creditworthiness. Our analysis suggests that sovereign-related exposure to a mismanaged climate transition is likely a much bigger risk to Colombian financial institutions than their direct exposure to the sectors analysed in this study.

Figure ES-7: **Climate transition risk transfers to government**[27]



27. Source: WTW and UniAndes analysis. For more detail, see chapter 4.

What are Colombia's options?

Despite the potentially destabilising consequences of the risks identified in this paper, the authors identified a range of potential actions available to Colombia if it recognises and deals with the risks proactively. We use the analysis, which breaks new ground in the level of detail applied to this problem in the Colombian context, plus the authors' experience of analysing and advising on international transition issues to provide recommendations on potential solutions.

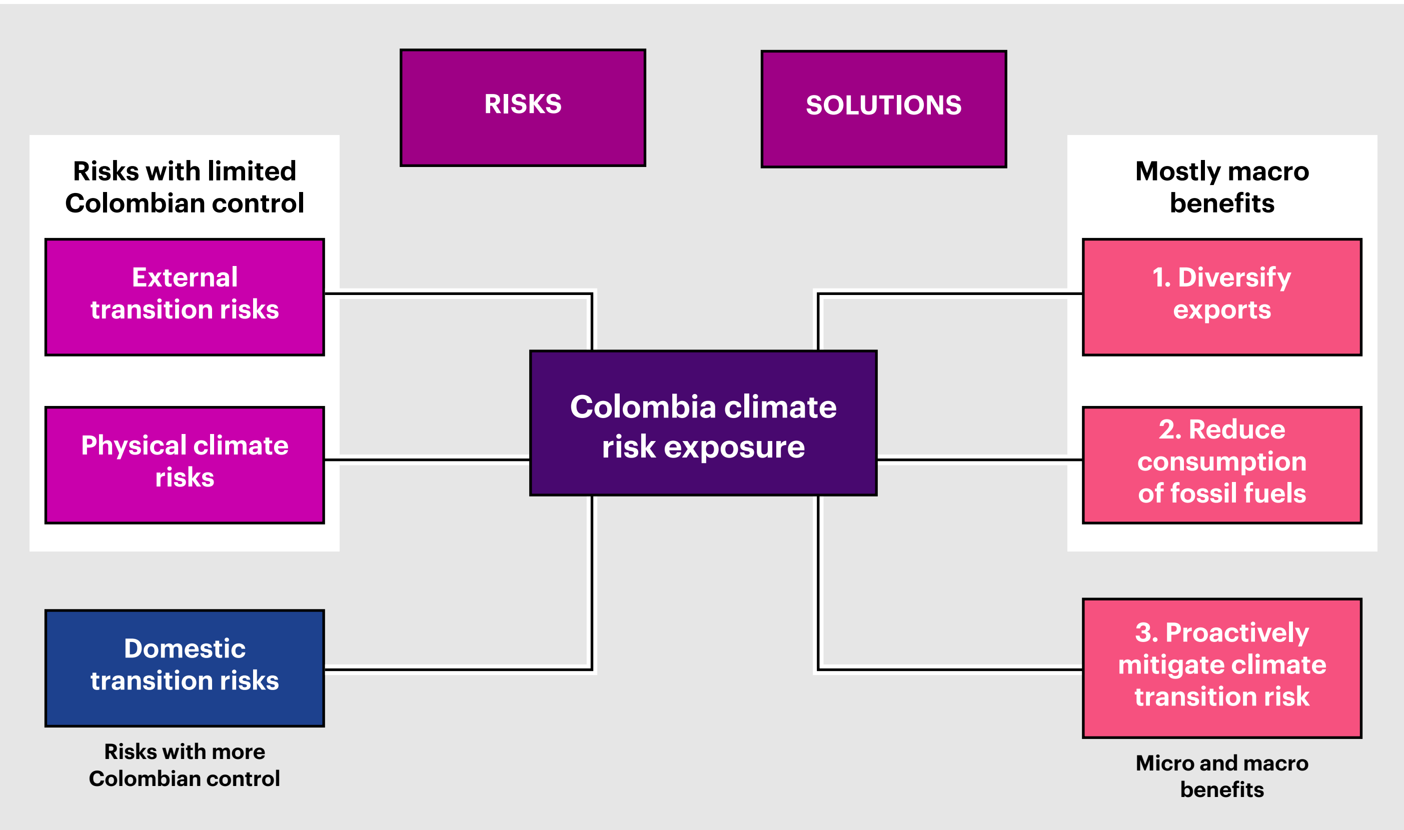
The design of Colombia's response to the climate transition risks identified in this paper should be informed by four key variables: 1) **timing;** 2) **geography;** 3) **distribution** (among economic groups or parts of the economy; and 4) **resilience to different climate transition scenarios.** We add a further cross-cutting consideration: whether paths taken in the short term prevent or increase the cost of taking an alternative long-term path to meet Colombia's E2050 goals (**path dependency**).

We argue that Colombia should prioritise actions first to mitigate the material risks that it has limited control over. Doing this would "de-risk" Colombia's future domestic decarbonisation decisions (and therefore, it's sustainable development trajectory) by providing an effective insurance policy against the potentially destabilising consequences of the risks set out this paper.

No one solution is likely to be sufficient to mitigate the risks that we identified. For example, Colombia has a range of options for diversifying its export revenues away from coal and oil. These include industries, such as agricultural products, where the new government has identified potential scope for growth in the short term. This strategy would increase Colombia's economic resilience regardless of whether a global transition occurs. However, while the growth of agricultural exports could help to alleviate volatility in the trade balance and hence, in the value of the Colombian peso, it would not provide a direct replacement for fiscal revenues, such as extractive industry royalties, that would decline in an accelerated global transition. By contrast, a scale-up in up the mining of "transition metals" (metals whose use is likely to be much higher in a more deeply decarbonised world), particularly copper, could provide an alternative source of resource rents although large scale benefits are unlikely to materialise for close to a decade. At the macro level, these industries are unlikely to be available to offset short-term declines in coal and oil revenues. In addition, they would not necessarily provide jobs and economic activity to the same workers and regions that face transition-induced decline.

Many of the points set out in the preceding paragraph have been made by those arguing that the new

Figure ES-8: **Summary of Colombian climate risks and potential risk mitigation solutions**



government's energy transition vision is too ambitious. Compared with new government's planned phase-out of Colombian oil and gas production, prolonging the domestic production of natural gas would be one way of reducing future Colombian imports (a macro-level benefit) and prolonging a source of revenue for local governments. However, it would do nothing to mitigate the potentially destabilising downside risks (at either micro- or macro-level) relating that we have identified in relation to the impact of global transition. Major long-life investments in new gas infrastructure could also create path dependency relating to Colombia's domestic transition, potentially making the latter more expensive and more volatile than alternatives.

The new government's plan for a unilateral reduction of fossil fuel production could create significant short-term economic risk unless sufficient and appropriately ambitious action is taken to accelerate the take-up of and investment in non-fossil fuel alternatives. This report offers several suggestions as to why accelerating the scale-up of "low carbon demand" may be even more important for Colombia's climate ambition than winding down "high carbon supply" and why doing so is also likely to be one of Colombia's most powerful options to mitigate risks from the global transition.

Any Colombian climate transition risk mitigation strategy will remain subject to uncertainty, because of the uncertain and constantly changing shape and speed of different transitions in different sectors and geographies. The core recommendations explained below are designed to help Colombia "de-risk" this strategy by planning to mitigate risks, whose probability is rising, and which could have extremely high impact if they arise.

We are conscious that this diagnosis and these recommendations are only likely to represent an important early step, rather than the end, of in-depth discussions about Colombia's decarbonisation strategy. Successfully achieving and implementing these recommendations is likely to require a joint effort between the government, the private sector, academia, and civil society.

7. To ensure that Colombia's transition is orderly and achieved at the lowest possible costs, policymakers, regulators, and investors should incorporate climate transition risk analysis into decision-making processes.

Effective management of the material risks identified in this paper represents a significant challenge that would be made more manageable if an understanding of climate transition risk were embedded into policymaking, regulatory, and investment decision-making processes in a systematic and, as far as possible, co-ordinated, fashion. Achieving this aim may be difficult because of the still nascent understanding among key decision-makers about climate transition issues and the tools needed to analyse them. The authors were also struck by the disbelief of many Colombian interlocutors about the technical or economic possibility of alternative low carbon systems or even their desirability, despite ambitious international policy commitments made by the Colombian government.

In order to be able to design a comprehensive and internally consistent response to the risks set out in this paper, it will be important for Colombian policymakers to draw on independent advice that draws on the best of international and Colombian expertise. Creating an independent body with a legislative mandate to provide advice on these topics (for example, like the UK's Climate Change Committee) could be useful given the complexity of the task. The data and analysis resulting from this project could be an important input into this implementation phase, providing an analytical framework that can be used to "stress test" existing and planned policies and public investments and a conceptual framework to address other important climate-related externalities out of the scope of this study (including physical climate risk and nature-related risks).

In addition to the institutional challenges referenced above, this climate transition risk analysis highlighted several areas of lingering uncertainty about the detailed plans for Colombia's decarbonisation, which may create space for partial analysis, misunderstanding and lobbying on behalf of different energy and industrial industries. These uncertainties also create risk for potential providers of investment in low carbon technologies, despite helpful guidance from the SFC and via the green taxonomy.

In our view, two items are most urgent: 1) accelerating the development of knowledge about the costs and practicalities of deploying CCUS technology at scale and 2) providing transparency around detailed plans to reduce Colombia's emissions from land use sectors.

Understanding these items, plus other core priorities identified in table ES-2, would give firms (and their investors and workers) better information about the expected speed of Colombia's low carbon transition in energy and industrial sectors and the viability of using natural gas as a "transition fuel" and for how long. For example, for Colombia to meet its E2050 targets and to continue to use natural gas in the long-term (whether in power, industry or transport) will depend on the ability to capture and store greenhouse gas emissions from its combustion or processing. Until the site-specific costs of Colombia's potential CO2 storage assets are better known, it is not possible to say whether natural gas will be cheap or expensive as an energy source, relative to low carbon alternatives.

Table ES-2: **Key uncertainties relating to Colombian climate policy identified for urgent for future research**

Urgent issue for further study	Sector-specific or cross-cutting	Current sources of uncertainty
Carbon capture, utilisation, and storage (CCUS)	Cross-cutting	Underpins viability of continued long-term use of natural gas in Colombia, but very little understanding of geological storage potential and infrastructure costs
Agriculture, Forestry, and Land Use (AFOLU)	Cross-cutting	Pace of Colombian decarbonisation in non-AFOLU sectors depends on successful conversion of AFOLU sectors from Colombia's biggest source of GHG emissions to a net sink.
Biofuels and biomass	Cross-cutting	Viability of scaling up land use targeted at biomass and first-generation biofuels, given challenges to reduce AFOLU emissions. Long-term viability of first-generation biofuels and practical challenges with scaling up second and third generation biofuels (including links with waste sectors). Understanding of which sectors to prioritise given limited biofuel supply
Options for flexible "clean firm" power generation	Sector-specific	Current Colombian planning assumption that some form of coal- or natural gas-fired power will be required in 2050 does not accord with international developments on "clean firm" power. Decisions on "clean firm" power will impact CCUS plans
Decarbonisation pathways for industrial sectors	Sector-specific	Policy planning for liquid fuels, coke, steel, cement, and other industrial sectors needed to help drive decarbonisation investment and to make explicit potential trade-offs between cost and security of supply
Infrastructure planning	Cross-cutting	Required size, location, and timing of new network investments (electricity, gas, hydrogen, CO2) will be different depending on sectoral plans
Alternative economic models with less reliance on fossil fuel rents	Cross-cutting	For an orderly transition to a new economic model, understanding the trade-offs of potential alternatives will be key

Policy, regulation, and investment decision-making that does not adequately account for the risks set out in this paper or the key uncertainties set out in table ES-2 risks increasing Colombia's climate transition risk exposure above and beyond $88 billion through investment in new assets that face future stranding.

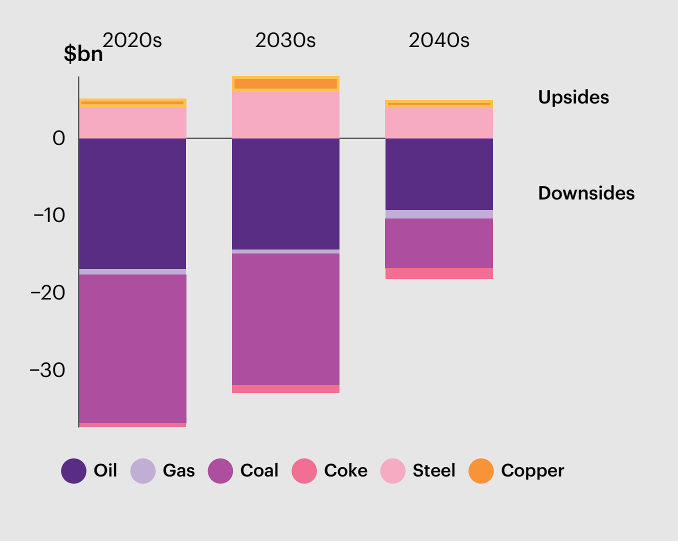
8. Colombia should continue to take proactive steps to diversify the export basket, including through potential opportunities in transition metals and synthetic fuels. This would be beneficial regardless of the speed of the global transition although large scale benefits may not arise early enough to offset climate transition downside risk.

Colombia's new government and central bank[28] have both recently recommended that Colombia prioritises actions to diversify the country's export basket and has identified short-term opportunities to grow agricultural exports and the tourism. This strategy would help to reduce volatility in Colombia's external balance, regardless of the global transition, although the global transition does offer Colombia certain opportunities to develop new export sectors.

Our analysis suggested that Colombia has a particularly strong opportunity in mining copper, a metal for which demand is expected to rise sharper in a faster global transition, and potentially also in mining nickel. If the country is successful in its plan to produce very low-cost green hydrogen from renewable energy and electrolysis, it could also open the door for Colombia to become a successful exporter of hydrogen derivatives including low carbon shipping fuels.

However, there remains uncertainty around the timing of these opportunities. Colombia's largest copper mining prospects have faced challenges obtaining environmental licenses, while investment flowing in wind and solar power generation has been slowed as investment in electricity networks has not come at the same speed. New export industries could help to offset some (potentially a lot) of the impact of climate transition risk on Colombia's external balance, but more likely starting at scale in the 2030s. This means that finding a like-for-like replacement of one source (thermal coal) of export revenues (let alone associated jobs, royalties, and taxes) with another is unlikely. Boosting exports from non-transition-related Colombian sectors, such as industry and agriculture, may also take a while to implement, given long-running challenges around electricity prices, low agricultural productivity, and inland logistics costs.

Figure ES-9: **Timing of downsides and potential upsides[29]**



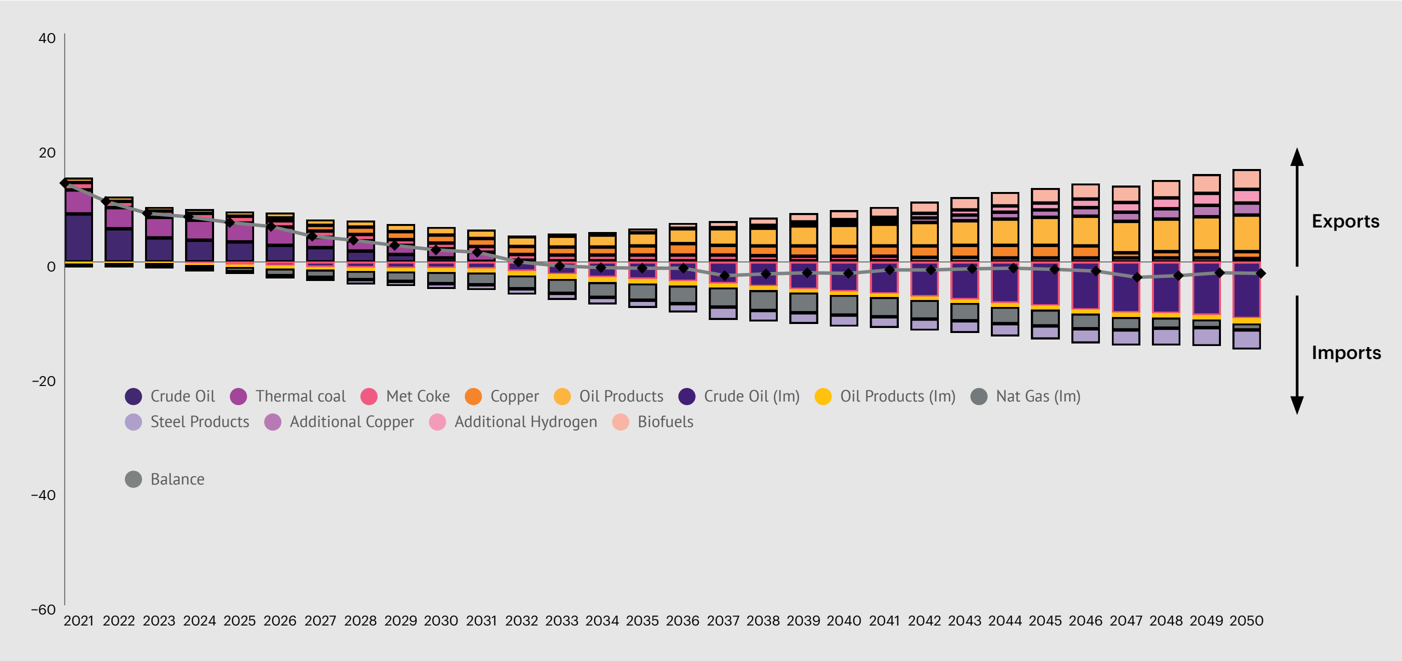
9. Accelerating Colombia's domestic transition, particularly in transport and industry, brings an opportunity to mitigate external climate transition risk, by reducing future imports of oil and gas and helping to incubate hydrogen-related export industries

In addition to developing alternative sources of export revenue, Colombia can use the design of its domestic transition deliberately to help mitigate the structural decline in the external balance. It can do this by developing faster decarbonisation pathways for transport and industrial sectors that reduce reliance on imported oil and natural gas. Using policy to grow domestic demand for green hydrogen in power, transport and industry could help bring down costs of hydrogen production which could then support the growth of an export-sized hydrogen industry. Achieving this will be conditional on a significant scale-up in renewable energy generation capacity, which has historically been stymied by grid constraints. Scaling up distributed generation may help to obviate the concerns of those opposed to major transmission network upgrades.

The combination of pursuing more non-coal and hydrocarbon exports and using a domestic transition to reduce hydrocarbon imports, could potentially go a long way to righting the external imbalance over the long run.

28. See Bernal-Ramírez, J. et al (2022)
29. Source: WTW and UniAndes analysis. For more detail, see chapter 5.

Figure ES-10: **Colombia's potential future trade balance in transition-exposed sectors (WB2C) including a growth in transition-related exports and the impact of lower domestic oil and gas consumption**[30]



10. The government should proactively target support for parts of the economy that face climate transition risk but have limited capacity to bear it. Where appropriate, it may be able to draw on sources of fiscal revenue (including additional taxes during periods of high commodity prices) as well as new international sources of funding targeted at these issues

Even if a proactive approach can help to repair a structural decline in Colombia's external balance, additional action will be needed to help support those more vulnerable parties that face climate transition risk and but have few options to deal with it. Those include the workers, communities and small firms mentioned in key finding 5 but also include parties that are resilient to a global transition but likely to face downside risk in a domestic transition.

This study has placed less emphasis on quantifying risks from a domestic transition, given the limited amount of detail at the sectoral level relation to the policies and investments needed to implement the E2050 vision. These are likely to include firms owning power plants that shut down earlier than planned in an accelerated Colombian domestic transition (coal fired power plants and the least efficient and least flexible gas-fired power stations[31]). Certain industrial sectors, including steel, textiles and pulp and paper may also face import substitution risk if the cost of investing in the decarbonisation of processes hurts Colombia's competitiveness against imports from countries decarbonising more slowly than Colombia. Other industrial sectors, particularly those that have unresolved technical challenges with the replacement of fossil fuels (those requiring high temperature "direct" heat, such as cement and lime) and those where activities are split between many small facilities (such as glass and brick), face particular challenges, as would domestic market-oriented coal and natural gas producers unless Colombia can scale-up a carbon capture, use and storage (CCUS) industry quickly, safely and at scale.

Government should be proactive and put in place dedicated support for workers, local governments and potentially, small firms facing concentrated climate transition risk and do so well in advance of those risks crystallising. While an alternative funding model for local governments is likely to be required in time, our analysis shows that a dedicated transition fund, financed by an additional tax on the profits of thermal coal and crude oil exporters during periods of high global commodity prices could raise more than $20 billion to support an orderly transition[32].

However, given the pressure on the public balance sheet identified in this paper, Colombian policymakers should also explore the benefits of accessing emerging new international sources of transition- and climate-related financing, including government-to-government exchanges such as the Just Energy Transition Partnership being pioneered in South Africa and private philanthropic funders mostly based in the global north.

30. Source: WTW and UniAndes analysis. See chapter 5 for more detail. NB. The "upside" figures for additional copper, biofuels and additional hydrogen are purely illustrative.
31. The extension of the scope of Colombia's carbon tax proposed in the new tax reform would accelerate the domestic climate transition risk exposure of Colombian coal-fired power plants and coal miners, although since the former are mostly state-owned, the risk of spillover to the broader economy is lower. Source: https://assets.ey.com/content/dam/ey-sites/ey-com/es_co/topics/tax/ey-tax-alert-colombian-tax-reform-bill.pdf?download
32. The tax reform proposed by the current government incorporates a version of the tax proposed by this recommendation, but does not earmark the funds for transition-related purposes

1. Introduction

Figure 1: **Map of Colombia**[35]

Colombia is one of the most biodiverse countries in the world[33]. Situated in the north-west corner of the South American continent, Colombia stretches from the Caribbean in the north to the Amazon in the south. Most of the country's population of more than fifty million[34], and including major cities Bogotá (the capital), Medellín and Cali, live in the region around the Andes Mountain range, which runs north-east to southwest across the country.

The current Republic of Colombia was formed in 1886[36], however, the country's history has been marked by periods of conflict. Most recently, in 2016, a peace agreement was signed that was designed to end what journalists have called "Latin America's longest and bloodiest civil war"[37]. Despite this challenging political backdrop, Colombia has endured a period of relative economic stability, compared with neighbours[38]. Colombia benefitted from the mid-2000s commodity price "supercycle"[39] and used some of those gains to implement policies that made a significant dent in absolute poverty levels[40]. The country has a reputation for prudent policy and regulation[41], which have ensured that it has been able to weather the global financial crisis of 2007 to 2009 and the increasing commodity market volatility of the last five years without destabilising crises. In 2022, Colombian oil and coal exporters benefited from the spike in commodity prices that has been exacerbated by the war in Ukraine and international sanctions on Russia[42].

However, Colombia's economic reliance on fossil fuel industries[43] makes it and its economic model vulnerable to the long-term structural changes in global energy use that have been accelerated by Paris Agreement goals of keeping global warming to well below 2 degrees (WB2C) above pre-industrial levels. In 2019, more than half of the country's exports came from thermal coal, metallurgical coke, and oil, while key energy and energy-related sectors contributed 10.3% of GDP[44]. The sector's workers had a torrid COVID-19 pandemic, but in 2022, direct employment across mining and hydrocarbons sectors has once again risen above 300,000[45].

33. See: https://www.cbd.int/countries/profile/?country=co
34. See: https://data.worldbank.org/indicator/SP.POP.TOTL?locations=CO
35. Source: Google Maps
36. See: https://en.wikipedia.org/wiki/Colombia
37. See: https://www.ft.com/content/0b6107be-0448-4e6d-b287-54fc31a49e9b
38. Since Colombia first gained a sovereign credit rating from Moody's Investors Service, the country's rating – a proxy for public debt sustainability – has had limited fluctuation, moving between slightly weaker than "investment grade" with weakest point of Ba2, and a weak investment grade, with a strong point of Baa2 (see: https://www.moodys.com/credit-ratings/Colombia-Government-of-credit-rating-186200/summary). By contrast, neighbouring Ecuador (https://www.moodys.com/credit-ratings/Ecuador-Government-of-credit-rating-600023694/summary) and Venezuela have suffered defaults and Brazil has faced much greater fluctuation in ratings (implying greater economic volatility), from a weak point of B2 for much of the 1990s to a strong point of Baa2 (https://www.moodys.com/credit-ratings/Brazil-Government-of-credit-rating-114650/summary)
39. See: https://blogs.imf.org/2018/06/21/how-the-commodity-boom-helped-tackle-poverty-and-inequality-in-latin-america
40. See: https://www.worldbank.org/en/news/feature/2016/01/14/colombia-winning-the-war-on-poverty-and-inequality-despite-the-odds
41. See: https://www.worldbank.org/en/country/colombia/overview
42. See: https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/coal/062222-colombia-coal-receipts-set-30-year-record-high-in-april-dane
43. According to https://www.dane.gov.co/index.php/estadisticas-por-tema/comercio-internacional/exportaciones#:~:text=De%20acuerdo%20con%20la%20informaci%C3%B3n,ventas%20externas%20del%20grupo%20de, in 2019, 55% of Colombia's exports were from crude oil and oil products, thermal coal and coke.
44. Source: DANE. This figure includes GDP contributions from the following sectors: a) coal and lignite mining, b) oil & gas extraction and supporting activities, c) coking and refining, d) basic chemicals, fertilisers and pharmaceuticals, e) plastic and rubber, f) electricity generation, transmission, and distribution, and g) supply and distribution of gas, steam, and air conditioning.
45. See government estimates on employment in mining and hydrocarbon sectors from: https://mineriaencolombia.anm.gov.co/sites/default/files/2021-08/Fact%20Sheet%20Colombia%2008%202021.pdf

There is now strong consensus that in a world that is successful in meeting Paris Agreement goals will be one in which demand for oil, gas, and particularly the coal that is used in power stations (thermal coal) will decline sharply, negatively impacting on price and profits and putting pressure on royalties and taxes for producing countries[46]. Not only would lower long term prices make the fossil fuel extraction businesses will be less lucrative than it would be in a world with a slower decarbonisation, but global financial markets are increasingly starting to shun investments (particularly in thermal coal[47]) and start to reallocate capital it to industries that will grow in a low carbon world (such as renewable energy, green hydrogen or zero-carbon steel). The combination of government policy, the changing behaviour of financial institutions and the increasingly assertive position of the world's central bankers who see climate-related financial risk as a threat to global financial stability, has prompted increasing numbers of companies and countries to make "net zero" pledges[48].

To-date, Colombia has remained relatively insulated from these trends. A relatively small contributor to global greenhouse gas emissions with[49] and with one of the cleanest electricity systems in the world[50], Colombia has faced relatively little international pressure on decarbonisation, compared with similarly sized emerging economies like South Africa. The country's financial regulators (Superintendencia Financiera de Colombia or "SFC") and central bankers (Banco de la Republica or BanRep) have been early, active and forward-thinking members of international fora on climate issues, such as the Network for Greening the Financial System (NGFS)[51]. The country has been a pioneer within Latin America on the use of thematic "green" sovereign bonds to diversify its investor base and reduce its debt costs[52]. Colombian policymakers have made very well-received pledges about national climate targets, including enhancing the ambition of its Nationally Determined Contribution (NDC)[53], pledging to reduce deforestation (historically by far, the largest source of Colombia's greenhouse gas emissions) to "net zero" by 2030[54], and reaching "net zero" on an economy-wide basis by 2050. In recent months, the country has moved to put these plans into action through the publication of its 2050 strategy (Estratégia 2050 or "E2050")[55], an Energy Transition CONPES[56] and several other more detailed policies aimed at implementation (and referenced in chapter 2).

For years, the structure of Colombia's (and other countries') national planning around climate change has been shaped by the institutions and technical language of the multilateral climate negotiations convened under the United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC process casts countries as the primary planners of "mitigation" and "adaptation" actions, set out in periodically updated national pledges. Under the Paris Agreement, signatories committed to submit short-term and long-term emissions reduction plans, setting out a series of planned actions, including investments[57]. Developing country plans often also include conditional targets dependent on the transfer of sufficient "climate finance" (i.e., climate-related financial flows from developed to developing countries). An industry of non-profits and private sector consultants and advisers has emerged to help countries develop these plans, which often include complex analysis including the use of climate and economic models and the assessment of technical feasibility of various potential climate solutions.

At the heart of a system based around national actions and national governments as the agents of those actions has also been a long-running debate about who bears responsibility for global warming and who should pay for its costs. If developing countries bear less responsibility than developed countries, then why – so the argument goes - should they pursue deep decarbonisation (typically formulated as "net zero" targets) today and put at risk their own economic development?

46. See the International Energy Agency's World Energy Outlook (2021), perhaps the most broadly recognised provider of globally consistent energy transition scenarios (https://www.iea.org/reports/world-energy-outlook-2021). In the IEA's "Sustainable Development Scenario" that we use as one input into the well-below two degrees Celsius (or WB2C) scenario used in this study, demand for thermal coal would be 86% lower in 2050 than in 2019, demand for crude oil, 51% lower and demand for natural gas, 40% lower. The implications for prices, royalties and taxes set out above, are also referenced in the IEA's report, but also in this study and in studies by other parties, including the Inter-American Development Bank (see: https://publications.iadb.org/en/fiscal-policy-and-climate-change-recent-experiences-finance-ministries-latin-america-and-caribbean), a very important stakeholder for Colombia.
47. See: https://ieefa.org/coal-divestment for an up-to-date list of coal "divestments", withdrawals and non-renewals by financial institutions
48. See: https://ca1-nzt.edcdn.com/@storage/Net-Zero-Stocktake-Report-2022.pdf?v=1655074300 for a review of net zero pledges as at June 2022. These include governments of countries representing 83% of global emissions and 91% of global GDP (PPP)
49. In 2018, the most recent date according to Colombia's published greenhouse gas emissions inventories (https://unfccc.int/sites/default/files/resource/BUR3%20-%20COLOMBIA.pdf), the country emitted 279.2 million tonnes of CO2 equivalent, net of absorptions. This represented 0.6% of global greenhouse gas emissions in the year, according to: https://www.wri.org/data/world-greenhouse-gas-emissions-2018
50. See: https://blogs.iadb.org/energia/en/solar-and-wind-energy-will-transform-the-colombia-energy-matrix/
51. SFC joined the NGFS in the first quarter of 2019, as per (https://www.ngfs.net/en/communique-de-presse/ngfs-calls-action-central-banks-supervisors-and-all-relevant-stakeholders-greening-financial-system-0), with BanRep joining later in the year.
52. See: https://www.environmental-finance.com/content/awards/environmental-finances-bond-awards-2022/winners/green-bond-of-the-year-sovereign-republic-of-colombia.html#:~:text=The%20Republic%20of%20Colombia%20secured,bond%20in%20its%20domestic%20market.
53. In Colombia's updated NDC, the country commits to reducing GHG emissions in 2030 by 51% compared baseline trajectory: https://unfccc.int/sites/default/files/NDC/2022-06/NDC%20actualizada%20de%20Colombia.pdf
54. At COP26 in Glasgow, Colombia committed to ending deforestation by 2030, net of new trees planted. See: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/273337/joint_statement_deforestation_colombian_amazon.pdf
55. For a summary of the E2050 vision, see: https://colaboracion.dnp.gov.co/CDT/Prensa/Publicaciones/Documento_vision_colombia_2050.pdf
56. Colombia's Energy Transition CONPES (see: https://colaboracion.dnp.gov.co/CDT/Conpes/Econ%C3%B3micos/4075.pdf) is a guiding document setting out a framework to guide future public policy actions with the objective of achieving Colombia's medium- and long-term decarbonisation goals. This framework has been be augmented by the new Plan Nacional de Desarollo and will be complemented by detailed policy documents, which will be the main drivers of implementation.
57. The Paris Agreement "Rulebook" was completed at COP26 in Glasgow, now setting out clear guidance for countries in terms of their decarbonisation planning. For a summary of the changes at COP26, see: https://www.allenovery.com/en-gb/global/blogs/countdown-to-cop/the-paris-rulebook-after-cop26

In recent years, an increasing body of analysis – including by the authors of this report[58] – has started to show that, while the equity questions of climate action and climate finance cannot be ignored, the economic arguments and analyses set out by many countries in favour of very gradual domestic transitions are underestimating two very important issues.

Firstly, national low carbon transitions do not happen in a vacuum. As countries start to reduce their greenhouse gas emissions (or at the very least, reduce the carbon intensity of development), they do so amidst an accelerating series of structural changes happening at different speeds in different parts of the world (Germany and Sweden have set net zero targets for 2045, China and Indonesia have set them for 2060 and India, for 2070[59]) and in different industrial sectors (decline in the use of coal in power stations is likely to happen earlier than in cement production). These structural changes in demand will have a range of impacts on the largest global commodity markets and global trade more broadly, affecting all countries – exporters and importers.

Secondly, an overwhelming majority of the capital required to fund climate change mitigation and adaptation action across the world is concentrated in the developed world in jurisdictions taking the lead in the conceptualisation and integration into financial supervision of the notion of climate risk. As developed world financial institutions increasingly start to factor climate transition risk into investment decisions, investment will increasingly shift from industries facing long-term decline to those with more robust long-term growth prospects. The still nascent extension of climate risk analysis of corporate equity and fixed income securities to sovereign bonds[60], may mean that capital may become harder to attract for countries seen as decarbonisation "laggards" rather than "leaders".

To prepare for these global paradigm shifts, Colombian policymakers, regulators, and central bankers have begun the process of trying to understand the nature of climate transition risk. This paper builds on that initial research and thinking (which is summarised in chapter 2) and is designed enhance the understanding of Colombian policymakers, SFC and BanRep as to the nature of the risks that Colombia faces – at about the micro- and macro levels. In particular, the authors present detailed insights about potential impact of a global transition on economic and financial stability in Colombia, and how the global transition may affect the relative costs and benefits of different potential domestic transition pathways. The report also highlights likely transmission channels through which economic and financial risks arising from transition dynamics can propagate through the Colombian system and impact not just firms in affected sectors, but workers, communities, local and national public finances, and financial institutions.

The report also sets out a series of recommendations for those parties as to how they can incorporate climate transition risk considerations into their planning, policy, supervisory and regulatory exercises with the aim of mitigating the risks identified in this paper and preventing destabilising shocks. The authors concluded that, when considering a response to the risks identified in this paper, the questions of timing and risk allocation will be crucial. If fossil fuel supply is wound down faster than demand for zero carbon energy (such as renewable electricity, clean hydrogen, and biofuels) is wound up, the Colombia could end up with higher-than-expected transition costs. If climate transition risk is allocated – explicitly or implicitly – onto parties with limited scope to bear it, such as workers, communities, and local governments, then the government may lose social and political consent for the transition, increasing the likelihood that a higher carbon Colombia might, instead, face material physical climate risks. The physical consequences of climate change will increase sharply if Paris Agreement goals are not met and could have economic consequences magnitudes higher than the cost of a Colombian transition[61].

As part of the deliverables for this project funded by the Agence Française de Développement (AFD)[62], the authors have also provided certain data to the recipient ministries, led by the Departamento Nacional de Planeación (DNP), to support the consideration of which recommendations could be implemented.

58. This methodology has been developed and elaborated in previous reports including: https://www.climatepolicyinitiative.org/wp-content/uploads/2019/03/CPI-Energy-Finance-Understanding-the-impact-of-a-low-carbon-transition-on-South-Africa-March-2019.pdf and https://www.climatepolicyinitiative.org/publication/understanding-the-impact-of-a-low-carbon-transition-on-ugandas-plannedoil-industry/
59. For the countries whose plans it rates, Climate Action Tracker provides up to date information on country net zero targets at: https://climateactiontracker.org/
60. Moody's Investors Service has launched a climate transition risk (or "carbon transition risk") assessment for corporates (: https://www.moodys.com/research/ Moodys-tool-assesses-carbon-transition-risk-for-ratedcompanies--PR_410850) and has published ad hoc research on sovereigns (https://www.moodys.com/research/Moodys-Carbon-transition-risk-manageable-for-most-sovereign-oil-and--PR_386002), but does not appear to incorporate sovereign climate transition risk into ratings in a systematic fashion.
61. See: https://www.nature.com/articles/s41467-019-13961-1 as one of many available papers on this topic.
62. The project was funded by AFD's Facilité 2050 (Source: https://www.afd.fr/en/2050-facility#:~:text=new%20social%20contract.-,The%20AFD%20solution,to%20developing%20 long%2Dterm%20strategies.)

Structure of the report

The paper covers three main areas: a) a summary of how the work was designed to add value to historic and ongoing other research efforts in relation to the Colombian transition; b) a summary of Colombia's climate transition risk exposure by economic sector and split by time, location and economic group; and c) a detailed series of recommendations for policymakers, central bankers and regulators.

Chapter 2 explains the methodology used to quantify climate transition risk as well as the assumptions, data, scenarios, models, and approach used for understanding the allocation of climate transition risk in Colombia, starting from the micro level, and building up to systemic issues. This also sets the work in the context of ongoing related work by the DNP, SFC, BanRep and recent papers by World Bank and IMF analysts (references included in section 2).

Chapter 3 summarises the results of the analysis, including a quantification of downside risk from the global transition arising in economic sectors including thermal coal, metallurgical coal, coke, crude oil, oil products and natural gas. For each sector, we follow a common structure, explaining first the implication of global climate transition scenarios along with their impact on prices, margins, and investment budgets of Colombian producers. We describe the changes in market dynamics that result in differing cash flows between climate transition scenarios as "climate transition drivers". For each industry, we then explain the distribution of climate transition risk over time and point out where our analysis suggested that particular assets and related infrastructure (such as ports and railways) might be particularly impacted. Finally, we quantify climate transition risk for each sector as a net present value (NPV) of the difference between the sector's cash flows in a "business as usual" (BAU) scenario and a lower carbon "well below two degrees Celsius" (WB2C) scenario.

Chapter 4 takes the results set out in chapter 3 and considers the way in which Colombia's existing suite of policies, regulation, contracts, and financing structures would allocate these risks in the economy (between firms, workers, local and national government and the financial sector). We describe this type of risk allocation as "explicit risk". This chapter also considers how the distribution of risks and costs is likely to change over time via the strategic behaviour of firms and the actions of the national government seeking to manage climate transition risk. This chapter is particularly important as it explains how the significant economic and financial risk described in chapter 3 could, if left unmonitored, become destabilising for Colombia, particularly for its external balance and its sovereign credit rating. It is the insights in this chapter which are the source of the urgency with which we make the recommendations set out in chapter 5.

Chapter 5 lays out the detailed recommendations of the authors on how Colombian policymakers, regulators, and central bankers should best respond to the challenges outlined in chapters 3 and 4. These recommendations are structured along four themes. First, we argue that the government should pursue "no regrets" (i.e. where the action would be beneficial whether a global transition plays out or not) measures to diversify Colombia's export basket away from fossil fuels. This includes analysis of the growth potential for mining commodities, such as copper and nickel. Second, we argue Colombia can offset some of the risks identified in chapters 3 and 4 using the design of its domestic decarbonisation pathways. We then identify the risk concentrations likely to be remaining after implementing the first two sets of recommendations and explain how these, plus additional downside risk arising from the domestic transition, can be mitigated. We also identify potential sources of funding that can be used in this endeavour. Finally, we explain why and how embedding climate transition analysis into Colombian policymaking is a critical part of achieving the other aims set out above, and the implications this might have for domestic policy choices. Here, we address the question of whether a gradual Colombian transition is necessary less risky than an accelerated one. As an example, we subject to scrutiny the arguments in favour of relying on natural gas as a "transition fuel". We also highlight how providing enhanced transparency about the assumptions underpinning government planning can help to attract more and cheaper capital flows.

2. Measuring climate transition risk in Colombia

Key messages:

1. This paper evaluates the nature and magnitude of "climate transition risk" to Colombia, that is the economic and financial risks – both downside and upside – that are likely to arise as the world pursues deep decarbonisation. In this study, we have considered the impact of a change between the current trajectory ("business as usual" or BAU) and a lower carbon trajectory in line with the goals of the Paris Agreement ("well below two degrees Centigrade" or WB2C)
2. The methodology, developed by the WTW authors, uses techniques from financial analysis and microeconomic modelling to develop micro- and macro-level insights about the size of climate transition risk (measured as a net present value), the time over which it is likely to crystallise, and the distribution of risk within an economy.
3. The Colombia analysis uses 18 principal models, and uses thousands of datapoints to model cash flows for hundreds of assets and firms across the two climate transition scenarios
4. The core of the analysis is our investigation of key real economy sectors: thermal coal, metallurgical coal and coke, crude oil and natural gas, copper, power generation, transport, and industry
5. The analysis is strongly weighted towards quantifying the impact of the global transition on Colombia ("external" risk) as this is likely to arise sooner than domestic risk and is less within the control of Colombian policymakers.

2.1 Introduction

This chapter summarises the approach used to produce the analysis that underpins the results set out in chapters 3 and 4, as well as the recommendations in chapter 5. We also situate the methodology in the context of emerging best practice in international climate transition modelling and explain how the results are designed to add value to existing and ongoing Colombia-focussed work in this area.

To do this, we first define the "climate transition risk" that was the object of study (section 2.2) before explaining the general features of the modelling approach applied to the problem (section 2.3). We then specify in more detail the actual data, models, and scenarios used when completing the Colombia climate transition analysis (section 2.4). Finally, we explain how the study is designed to interact with and add value to other research efforts on climate transition risk in Colombia. For readers interested in greater detail about the architecture of the underlying models, the text in this chapter can be read in conjunction with Appendix A, which describes these issues in more detail.

2.2 Defining "climate transition risk"

"Climate transition risk" is a term that, in its original formulation, referred to the risk (potentially to the downside or upside) to the valuation of financial assets that could arise in different climate transition scenarios. Put simply, given that the characteristics of a world that decarbonises in line with the goals of the Paris Agreement will be very different from those of a world that does not reduce its greenhouse emissions, we would expect that the cash flows (and hence valuations) of many companies would be different in one scenario vs. another. At the core of that difference is climate transition risk.

"Climate transition risk" is a term that has become very well known among the world's central bankers, financial supervisors, and financial institutions, but much less so to policymakers. This is because climate transition risk was originally conceived as a financial risk, in financial terms[63]. Over the last five years, the Network for Greening the Financial System (NGFS), which has de facto emerged as the body defining a new best practice for central banks and financial supervisors on climate and biodiversity issues, has conducted an immense collaborative effort to try to understand, quantify and develop tools for monitoring and managing "climate-related financial risks" i.e. financial risks arising from the physical consequences of climate change ("physical risks") and from the structural changes required to deliver deep decarbonisation ("transition risks")[64]. NGFS members have expended so much effort on these topics, because of concern that the risks are not being priced and consequently being poorly managed. The institutions have also been also concerned that failing to manage climate-related financial risks effectively could be threats to global financial stability[65] and implicitly, also to the world's ability to mobilise capital to meet Paris Agreement goals at reasonable cost.

However, the focus on climate transition risk as primarily a financial system risk (perhaps because many of the original founders of the NGFS had suffered badly during the global financial system crisis starting in 2007), may have resulted in less attention to the potential consequences of climate transition risk for fiscal sustainability, local or national economic growth and worker livelihoods.

The authors contend that, if left unmitigated, climate transition risk can be destabilising in this broader sense and have constructed a methodology designed to provide insight on these issues to a range of policymakers, firms, and civil society, as well as central bankers and financial supervisors. To do this, the methodology needs to be useful for analysing both micro and system-level (or macro) dynamics.

2.3 General features of the methodology used in this paper

2.3.1. High-level summary

The methodology used in this paper draws mostly on techniques from financial analysis and microeconomics and can generally be described as analysing the problem of climate transition risk "from the bottom up".

Rather than analysing an economic or financial system through a stylised representation of a few real economy sectors and applying insights top-down to individual firms, the analysis used in this study builds up from a series of very granular microeconomic and financial models of sectors and firms facing concentrated transition risk[66] to a broader understanding of the risks to the real economy, public finances, and financial system and the transmission channels for these risks. This means that the work did not use a general equilibrium or other form of "macro" model, although the outputs from this analysis can be used as inputs to existing macro models, as described in section 2.5.

The general approach has been developed by WTW researchers (through the previous Climate Policy Initiative Energy Finance team that was acquired by WTW at the end of 2020) over the last 5 years, supported principally by AFD was piloted in South Africa[67] (2019), and has also been applied in Uganda[68] (2020) and in African natural gas-producing countries[69]. The approach was included as part of a guide for central banks by the Network for Greening the Financial System[70] (2020) and the analytical approach was cited as an example of important innovation in climate transition modelling by the Bank for International Settlements (2020)[71].

63. The Taskforce on Climate-Related Financial Disclosure (TCFD) has led the way in developing guidance for corporates and investors on disclosure of climate-related financial risks including climate transition risks, which can be found at: https://www.fsb-tcfd.org/
64. All NGFS publications are available here: https://www.ngfs.net/en/liste-chronologique/ngfs-publications
65. The Bank for International Settlements is one of a growing number of international central Banks and regulators concerned about the potential for unmanaged or undermanaged climate risk to trigger destabilising financial crises. See https://www.bis.org/publ/othp31.pdf as a good summary of currents of thinking
66. To identify target sectors, we conducted a scoping analysis in consultation with future steering committee members before the project started. Firms selected for targeted analysis were the largest ones in the sectors identified. The original scope focussed on export and port sectors which the authors determined faced transition risk where the drivers of that risk were relatively well known (for example, reduction of the use of coal in power stations) and emissions-intensive, non-AFOLU domestic sectors. The scope was extended to include assessment of potential new export sectors, such as copper and to include more detailed analysis of Colombian industry.
67. Ibid. Huxham, M. et al (2019)
68. Ibid. Huxham, M. et al (2020)
69. See forthcoming paper: Anwar, M., Neary, P. and Huxham, M. (2022) Natural Gas in Africa, amidst a global low carbon energy transition
70. See https://www.ngfs.net/en/case-studies-environmental-risk-analysis-methodologies for more detail
71. Ibid. Bolton, P. et al (2020)

The approach involves the following steps:
1) selection of real economy sectors for focused analysis; 2) collation of data relating to selected real economy sectors; 3) creation of relevant climate transition scenarios; 4) climate transition modelling at the sectoral level; 5) climate transition modelling at the asset level; 6) climate transition modelling at the firm level; 7) climate transition modelling for the value chain and adjacent infrastructure; 8) mapping of "risk allocation" or "transmission channels" from firms to the rest of the economy; 9) climate transition modelling for workers, local government, national government and financial institutions and assessment of potential implicit risk allocation and contingent liabilities. A further, optional step 10, can be the integration of the results of this analysis into other models, including macroeconomic models.

The rest of this section describes these steps in more detail.

2.3.2. Selection of real economy sectors for focused analysis

In advance of starting a piece of analysis using this methodology, we agree with the client a list of target real economy sectors. Focusing our analysis is important not just to ensure that the analytical process is manageable, but because the authors' research suggests that climate transition risk downside tends to be concentrated in sectors expected to decarbonise fastest (for example, the use of coal in power stations).

We typically select three or four sectors facing risk from a global transition (or "external" transition risk) and three or four sectors facing risk from a domestic or national transition in the country under study. Researchers seeking to reperform the analysis could make a choice of sectors as targeted or comprehensive as they like.

2.3.3. Collation of data relating to selected real economy sectors

For the chosen real economy sectors, where possible, we collate the following data:

Table 1: **Common asset-level data used in this methodology**

Data point	Level of analysis	Example
Maximum production capacity per year (or for each year, if the capacity is expected to change year on year)	Asset-level (for example, at the level of the individual power plant, coal mine)	Number of barrels of oil per day Power generation capacity in megawatts
Operating costs and expected incremental capital costs	Asset-level	Dollars per megawatt hour generated or per tonne of coal mined
Infrastructure costs and contract details	Asset-level	Rail and port costs per tonne handled (coal) Rail, port, trucking, shipping contract details (who bears volume and price risk)
Other technical characteristics	Asset-level	Heat rate (power plant) Nelson complexity[72] (oil refinery) Calorific value (coal)
Economics and timing potential new projects	Asset-level	Capital cost, construction period and planned timing of final investment decision
Ownership and contract data	Asset-level	Owners Production sharing contracts
Royalty and fiscal regime	Asset-level and firm-level	Royalty formula Corporate Income Tax rate
Financial structure	Asset-level and firm-level	Net Debt to EBITDA ratio Corporate credit rating Debt maturity analysis

If data cannot be sourced at the desired level of granularity, then analysts can use their own judgement to make approximations (for example, based on average costs for similar mines in a given region).

72. The Nelson Complexity Index (https://www.investopedia.com/terms/n/nelson-index.asp) is a means of ranking the relative sophistication of oil refineries. Most complex refineries are typically able to provide a larger share of higher value light products than less complex refineries

2.3.4. Creation of climate transition scenarios

Climate transition scenarios typically correlate to a particular level of global warming (such as an average 2 degrees above pre-industrial levels). Climate transition risk analysis typically considers the difference between a "business as usual" (or BAU) scenario and a lower carbon scenario (i.e., one with less warming potential). BAU scenarios should, in theory, represent current expectations on the most likely speed and shape of climate transitions and so should reflect the assumptions embedded in the market prices of financial assets, or in government policy. Thus, by definition, scenarios that assume lower or higher warming potential than that implied by the BAU scenario are not currently viewed as most likely. Lower carbon scenarios often used in climate transition analysis correspond to Paris Agreement goals of at least "well-below two degrees Celsius" (WB2C) or a more ambitious 1.5 degrees.

For country-level climate transition risk assessments, we typically define separate **global** scenarios, which impact that country's exports, imports, and some domestic prices and **domestic** scenarios. Defining separate domestic transition scenarios is important as global scenarios typically may not have sufficient granularity, especially to reflect the policies used to implement domestic transitions. Global scenarios are drivers of "**external risk**" with domestic scenarios driving "**domestic risk**".

The key outputs of climate transition scenario analysis for any given product or market are usually annual time series for a) **demand** (e.g. for each scenario, projections of future global demand for thermal coal in power stations); b) cost (e.g. for each scenario, projections of future incremental costs, such as that which could arise from carbon pricing); and c) **investment** (e.g. for each scenario, projections of future incremental investments required to maintain an operating license, such as that which could arise from retrofitting carbon capture).

For a given level of global warming potential, all sector-level climate transition scenarios need to be consistent – i.e., the combined emissions trajectory that results from each sector-level scenario needs to be consistent with a given total emissions trajectory that is consistent with those used by climate scientists.

A more recent innovation in the construction of climate transition scenarios is a move to create "disorderly" versions (i.e., scenarios corresponding to the same amount of warming potential as set out above, but where the trajectory towards lower carbon is less gradual). This trend recognises the fact that most publicly available climate transition scenarios explicitly or implicitly assumes an "orderly" trajectory towards a given end goal emissions point. Given the geopolitical hurdles associated with phasing out the use of fossil fuels and the practical challenges associated with orchestrating a gradual wind down of the fossil fuel economy, NGFS researchers have highlighted that "disorderly" scenarios could be more disruptive from the perspective of economic and financial stability[73]. In many ways, disorderly scenarios may well be more likely than orderly scenarios.

This means that the creation of climate transition scenarios tends to be a specialist exercise that can be difficult to replicate without significant investment in specialist in-house capacity.

2.3.5. Climate transition modelling at the sectoral level

Having chosen sectors, collated relevant data, and created global and domestic scenarios, the first step of climate transition modelling for each sector is to build a microeconomic model of that sector which, as far as possible, replicates the dynamics of that sector, including mechanisms of price formation and competitive dynamics.

The language and programme used to construct each model are typically tailored to the specifics of the market and its structure. For commodity markets, we typically construct models with asset-level supply data which use an optimisation function to simulate the economically optimal series of transactions, subject to any known constraints, such as contracted output or policy preferences, such as those around import substitution and security of supply. WTW analysts typically use construct models that require complex optimisations with thousands of datapoints (such as the in-house WTW seaborne thermal coal model) in Python, while relying on Excel for simpler tasks. More information about the models used in this project are set out in section 2.4, while more detail about the construction of our climate transition models is set out in Appendix A.

The key outputs from sectoral climate transition models for commodity sectors are market prices, often set by marginal pricing principles, constructed in line with policies applied in country (paying close attention to whether prices are set on an export parity or import parity basis or on a bilateral basis with limited connection to global markets). Depending on the market, these models can also provide information on whether a given asset is competitive in any given year, and hence whether it would produce.

73. See: https://www.ngfs.net/sites/default/files/medias/documents/820184_ngfs_scenarios_final_version_v6.pdf for an early summary of the financial stability challenges associated with disorderly scenarios

2.3.6. Climate transition modelling at the asset level

For sectors where asset-level data is being used, we use potential production and cost data (see section 2.3.3), together with price and volume information (section 2.3.4.) and research about any “government take” applied at the asset level (such as royalties) to construct simple cash flow profiles for each asset in each scenario.

For any given asset, the difference between the net present value (NPV) of future cash flows in a BAU scenario and in a lower carbon scenario represents climate transition risk (also climate transition value at risk or CTVaR). This method of valuing risk is a technique common to financial market participants. When making this calculation, we typically do not vary the discount rate between scenarios, although it is likely in practice that investor perceptions of risk are likely to change in a WB2C scenario compared with a BAU one. Analysts seeking to replicate this methodology could reasonably incorporate changes in discount rates between scenarios if there is sufficient data to quantify potential changes in discount rates.

These models are typically simple ones created in Excel, which would be relatively simple to replicate given all the above inputs. After asset-level modelling, we typically create a core project output: namely the climate transition risk exposure of a sector, which is made up of the aggregated climate transition risk calculations for each asset.

2.3.7. Climate transition modelling at the firm level

The next step is to aggregate asset- and segment-level cash flows at the firm level.

For a selection of companies in each real economy sector under review, we build a simple three-statement financial model, including the company’s actual capital structure. We integrate the asset level models into firm-level models, typically in Excel, to forecast future profits, corporate taxes, and free cash flows. We use firm-level post-tax free cash flows to calculate an enterprise value CTVaR and an equity CTVaR, using firm-level free cash flows available to shareholders.

Representing climate transition risk for a given company or financial security as a CTVaR is becoming increasingly common within the financial industry. CTVaR data are available for a wide variety of listed companies from data providers such as MSCI as well as WTW, although these are calculated in completely different ways[74]. These data increasingly inform the construction of investment indices[75] and climate- or ESG-related funds. The trend towards the disclosure of transition risk metrics by real economy and financial sector firms[76] may also increasingly allow climate transition risk to be factored into investment decisions and, ultimately, priced into asset valuations.

For country-level assessments of climate transition risk, we use firm-level financial models and credit analysis techniques to highlight firms at risk of financial distress (for example, via liquidity challenges, covenant breaches, or refinancing risk). Firm-level models are also the basis for starting to consider the exposure of the financial sector to climate transition risk (via ownership of shares of bonds or the provision of loans and other financial instruments) and risk allocation more broadly across the economy.

2.3.8. Climate transition modelling for the value chain and adjacent infrastructure

Having assessed climate transition risk for assets (section 2.3.5) and firms (section 2.3.6) in target sectors, we typically also consider the knock-on implications within value chains and for related infrastructure of climate transition risk in core sectors.

This analysis can be conducted at a variety of levels of granularity, depending on the availability of data. Examples could include oil refineries (closely linked to crude oil markets), rail lines, ports, and liquefied natural gas infrastructure.

2.3.9. Mapping risk allocation and transmission channels

The next step in the analytical process is the assessment of which parts of the economy bear the risks. For any given coal mine, revenues are used to pay for costs, including worker salaries and royalties, with any surplus or deficit accruing to the shareholders of the company/companies owning the asset. Profit-making firms are typically liable for corporate income tax.

74. WTW’s calculations of CTVaR are based on more granular assessments of likely transition pathways across economic sectors and geographies and consider other drivers of transition risk beyond carbon pricing. A snapshot of the methodology is set out here: https://www.wtwco.com/en-GB/Insights/campaigns/quantifying-climate-transition-risk
75. The STOXX Willis Towers Watson Climate Transition indices were first published in November 2021. Weightings are updated on a quarterly basis.
76. Transition risk metrics are one type of climate risk metric increasingly calculated, tracked and disclosed by firms. A good summary on the growing uptake of climate risk management can be found here: https://www.fsb.org/2021/10/2021-status-report-task-force-on-climate-related-financial-disclosures/

This part of the analysis typically involves desk research and interviews with local stakeholders into government policies, regulation, financing structures, contracts and any other formal mechanisms that allocate value and risk. Using this research, we create additional simple models (again, typically using Excel) to allocate risk from asset- and company-level models to other stakeholders, including workers, suppliers, infrastructure providers, local government, and national government. We term these formal mechanisms "explicit risk allocation".

2.3.10. Climate transition modelling for workers, local government, national government and financial institutions and assessment of potential implicit risk allocation and contingent liabilities

Finally, we use the asset (section 2.3.5) and firm level (section 2.3.6) assessments of climate transition risk, along with the research on risk allocation and transmission channels (section 2.3.8) to assess the exposure of other parts of the economy to whom risk is transferred from the real economy firms that initially face climate transition risk.

This part of the analysis can be tailored based on the client or user, with the level of detail as illustrated in table 2 below. However, what is common to each phase is an assessment (typically using credit analysis techniques) of the ability of any given party to bear risk and the level of financial flexibility that any given party has to take risk mitigate action. If portfolio data is available or if the analysis is being undertaken as part of a formal "stress test", the same analysis for individual financial institutions could also provide financial supervisors information as to the potential impact of unmitigated climate transition risk on capital adequacy and solvency ratios.

Table 2: **Analytical options for those seeking to perform deeper climate transition risk analysis into particular economic groups**

Potential bearer of climate transition risk	Potential analysis (depending on data availability)
Workers	Assessment of the extent to which labour costs and staff numbers vary with output Assessment of the extent to which trade union membership / contractual mechanisms provide protection against changes in employment terms, short of redundancy
Suppliers	Assessment of the ability to pass through climate transition risk to suppliers (contract terms, market structure dynamics) Credit assessment of major suppliers
Infrastructure providers	Assessment of the ability to pass through climate transition risk to infrastructure providers (contract terms, regulation) Credit assessment of major infrastructure assets / providers
Local government	Assessment of exposure to declining revenues relating to climate transition risk at the asset and firm level Assessment of exposure to rising costs and increase demand on services, arising from the climate transition risk of workers and suppliers Credit assessment, incorporating consideration of external financing structures and legislative restrictions on debt raising
Financial institutions	Assessment of exposures to declining asset values across equities, corporate and sovereign fixed income. Concentration risk for single name counterparties and sectors facing concentration climate transition risk Assessment of the impact of climate transition risk on other financial risks (including liquidity risk) and on capital adequacy / solvency
National government	Aggregated assessments from asset-level models and firm-level models of climate transition risk exposures Assessment of the impact of climate transition risk on macroeconomic variables and the knock-on impact of those on the public finances Assessment of the impact of climate transition risk on the macroeconomy and financial institutions and the knock-on impact for financial stability Assessment of the potential impact on the sovereign credit rating and the knock-on impacts on the macroeconomy and financial asset prices

Having conducted this analysis, we typically use desk research and interviews to consider potential risk mitigation strategies that the parties set out in the table above and the impact that those risk mitigation strategies might have on the overall mixture. We call this "implicit risk allocation". Parties who are unable to absorb or mitigate their risks are likely to fall into financial distress, resulting in "contingent liabilities" to the financial sector, the government or both.

Governments can often implicitly face additional contingent liabilities beyond those obligations that they have budgeted for. For example, we would expect that the national government may step in to support local governments who face declining revenues (i.e., royalties from declining mining industries) and financial distress. The impact of climate transition risk on the economic performance of key sectors, on national government revenues and costs and on the value of state-owned enterprises, could pose risk to the sustainability of national public finances with potential knock-on impacts for the future cost of raising sovereign debt and ultimately for the sovereign credit rating and for financial asset prices.

2.3.11. Integration of micro-level analysis into macro models

The steps and models set out above do not include an assessment of second- and third-round effects on local and national economies (for example, the potential impact of carbon prices on inflation, and subsequently on economic activity) nor the potential impact of financial sector-internal dynamics. These issues are likely to be important considerations for policymakers and regulators when assessing the materiality of the threat that unmitigated climate transition risk could pose for economic and financial stability.

Like climate transition scenario construction (section 2.3.4), macroeconomic modelling and financial system modelling are specialist activities. Where these already exist (for example, because they are currently used in ongoing surveillance activities by policymakers and regulators), these can be used to calculate additional system-level climate transition risk impacts. However, because the design of macro models typically includes limited infrasectoral detail, the points of coupling between this approach and many macro models can be limited to a few variables (for example, thermal coal prices and production volumes at a national level).

2.4 Applying this methodology to Colombia

This section summarises the design decisions relation to the application of the methodology set out in section 2.3 in Colombia.

2.4.1 Real economy sectors

The initial choice of target sectors was agreed in advance with steering committee members, based on a consultation about which sectors might face the greatest climate transition risk. The sectors tagged with an asterisk were added for high level analysis after the results of initial research.

Table 3: **Real economy sectors chosen for focus during the project**

Sector	External risk focus or domestic risk focus
Thermal coal	External
Metallurgical coal and coke*	External and domestic
Crude oil	External
Oil refining and oil value chain	External and domestic
Natural gas	External
Export-focused infrastructure	External
Power generation	Domestic
Transport	Domestic
Iron and steel	External* and domestic
Copper*	External
Cement and concrete	Domestic
Industrial sectors requiring low temperature heat* (sugar refining, pulp and paper, textiles)	Domestic

The period for analysis of all these sectors was set at 2021/22 to 2050.

2.4.2 Data and models

In the project, we compiled a wide variety of data from Colombian and international sources. Much of this data was publicly available, other data was only available under license or for purchase for a fee. Table 4 summarises the data and models used in the project[77]:

Table 4: **Summary of data and models used in the Colombia project**

Model	Modelling programme	Key inputs	Type of asset-level data	Key outputs (per climate transition scenario)
1. Global crude oil model	Excel	Oil demand scenarios Asset-level data[78] as per section 2.3.3.	Annual data for potential production and capital expenditure Static data on chemical composition, measured using API gravity[79]. Operating costs are stated as variable per unit costs and subject to inflation	Brent crude oil prices and adjusted realised prices for each asset
2. Global copper model	Python	Copper demand scenarios Asset-level data[80]	Annual data for potential production and capital expenditure. Static data on copper grade and copper refining costs. Operating costs as in model 1	LME benchmark refined copper prices and adjusted realised prices for each asset
3. Global steel model	Python	Steel demand scenarios Asset-level data[81] Global iron ore, metallurgical coal, and coke prices	Annual data for capital expenditure Static data production capacity and technical characteristics. Operating costs as in model 1, including coking costs	Global long and flat steel product prices Global metallurgical coal, coke, and iron ore prices Adjusted realised prices for each asset
4. Global iron ore model	Python	Steel demand scenarios Asset-level data[82]	Annual data for potential production and capital expenditure. Static data on iron ore grade. Operating costs as in model 1	Global prices for iron ore fines, lump, and pellet grades Adjusted realised prices for each asset

77. WTW's in-house global commodity models were created separately to this project
78. Core asset-level data obtained from Rystad Energy under license.
79. API gravity is a measure used to measure the relative density of different types of crude oil (https://www.mckinseyenergyinsights.com/resources/refinery-reference-desk/api-gravity/)
80. Core asset-level data obtained from CRU under license.
81. Core asset-level data obtained from CRU under license.
82. Core asset-level data obtained from CRU under license.

Model	Modelling programme	Key inputs	Type of asset-level data	Key outputs (per climate transition scenario)
5. Global metallurgical coal and coke model	Excel	Steel demand scenarios Asset-level data[83]	Annual data for potential production and capital expenditure. Static data on metallurgical coal energy content Coking costs from model 3 Operating costs as in model 1	Global prices for metallurgical coal and coke Adjusted realised prices for each asset
6. Global thermal coal model	Python	Thermal coal demand scenarios Thermal coal production scenarios (China, India, Indonesia, US, Russia) Shipping cost scenarios Asset-level data[84]	Annual data for potential production and capital expenditure Static data on thermal coal energy, ash, and sulphur content Operating costs as in model 1	Trade flows Delivered (CFR) seaborne thermal coal prices at each key import node Adjusted realised prices for each asset
7. Global liquefied natural gas (LNG) model	Python	LNG demand scenarios Charter cost scenarios Asset-level data[85]	Annual data for potential production and capital expenditure Static data on thermal coal energy, ash, and sulphur content Operating costs as in model 1	Trade flows LNG import prices at each key import node Adjusted realised prices for each asset
8. Colombia "scheduling" models for thermal coal, crude oil, and natural gas	Excel	Asset-level data Outputs from models 1, 3, 6 and 7	As above, for potential new assets	Asset-level cash flows Closure and investment decisions
9. Global "scheduling" model for copper	Excel	Asset-level data Outputs from model 2	As above, for potential new assets	Asset-level cash flows Closure and investment decisions

83. Core asset-level data obtained from CRU under license.
84. Core asset-level data obtained from CRU under license.
85. Core asset-level data obtained from Rystad Energy under license.

Model	Modelling programme	Key inputs	Type of asset-level data	Key outputs (per climate transition scenario)
10. Sectoral models for power generation, steel, cement, and concrete	Excel	Some asset-level data and firm-level data, extrapolated to the industry	Static data on power plant efficiencies and some coal and natural gas contracts	Some asset-level cash flows, mostly cash flows for each type of asset
11. Domestic value chain modelling for liquid fuels and gas	Excel	Asset-level data on oil refineries and LNG terminal Fuel demand scenarios Fiscal information	Static data on oil refinery product slates[86] Operating costs as in model 1	Asset-level cash flows Crude oil imports Closure decisions
12. Domestic infrastructure modelling for rail, ports, pipelines, and LNG terminal	Excel	Revenue data taken from models 8-11 Asset-level cost data	Static data on rail, port, and pipeline capacity Operating costs as in model 1	Asset-level cash flows
13. Transport stock forecasting model	Excel	Freight fuel usage data Colombian domestic transition scenario	Annual data for expected (BAU) stock purchases and retirements[87]	Stock forecasts for vehicles with different fuel types Fuel demand scenario in accelerated transport decarbonisation and hydrogen sensitivities
14. Company financial models	Excel	Historic company financial information[88] Outputs from models 8-12	Three-year historic annual financial statements	Company CTVaR (enterprise value and equity) Company credit metrics and solvency analysis Corporate tax calculations
15. Regalías redistribution model	Stata	Outputs (royalty flows) from models 8 and 9 Information about SGR redistribution system	Research on the structure of the system	Royalty flows by departamento and município

86. Refinery product "slates" refer to the typical mix of refined products created from one barrel of crude oil. This is partly a function of the technical characteristics of the refinery, but partly also related to the characteristics of the crude it is refining (or its crude slate). See: https://www.breakthroughfuel.com/blog/refined-products-outputs/
87. Source: https://www1.upme.gov.co/DemandayEficiencia/Documents/Informe_final_Ascenso_tecnologico.pdf
88. For listed companies, historic financial information was taken from Bloomberg under license. For non-listed companies, we obtained information from EMIS.

Model	Modelling programme	Key inputs	Type of asset-level data	Key outputs (per climate transition scenario)
16. Local government financing models	Excel	Outputs (ICA and other municipal taxes) from models 8 and 9 Outputs from model 15	Annual historic[89] data about regalías spend	Income by local government (for selected local governments)
17. Employment calculation model	Excel	Outputs from models 8 and 9 Information about current employment[90]	Research on the structure of the system	Income of mining and oil and gas workers by departamento
18. National public finances model	Excel	Outputs from models 8, 9, 10, 14 Analytical outputs from models 16, 17	Annual historic[91] and projected data about Colombian national accounts	Fiscal flows State-owned enterprise value (particularly, Ecopetrol) Additional costs Impact on sovereign credit rating metrics

2.4.3 Scenarios

We compiled BAU scenarios designed to represent a world with no new climate policies introduced between ones that have been already implemented or announced. This scenario equates to around 2.7-3.1 degrees of warming[92]. Our lower carbon WB2C scenario implies warming being limited to around 1.75C[93] above pre-industrial levels[94]. Our global scenarios also implicitly assume an "orderly" transition, i.e., one where decline in emissions-intensive sectors is matched by growth in low carbon sectors.

2.4.3.1. Global scenarios

We focused more of our Colombia analysis on global scenarios and external risk because a) of the fact that external risk is likely to be material and could materialise earlier than domestic risk; and because b) no Colombian domestic sectors, as yet appear to have detailed deep decarbonisation implementation plans that are consistent with the E2050 vision.

We also judged that external risk, like physical climate risk, is an issue over which Colombia has much more limited control than domestic risk. Furthermore, the global transition could have a material impact on Colombia's external balance, introducing additional volatility into the value of the peso and the public finances (see table 5 below). The global transition could – directly and indirectly – affect some domestic prices (including those of oil products and natural gas), influencing the relative cost of different decarbonisation pathways.

Table 5: **Top ten largest Colombian export sectors in 2020 (Total $32.2 billion)[95]**

1. Crude Petroleum	$7.5bn	23.2%
2. Coal Briquettes	$4.1bn	12.8%
3. Coffee	$2.5bn	7.9%
4. Gold	$2.3bn	7.3%
5. Refined Petroleum	$1.6bn	4.8%
6. Cut Flowers	$1.4bn	4.4%
7. Bananas	$1.1bn	3.3%
8. Coke	$0.7bn	2.0%
9. Ferroalloys	$0.4bn	1.4%
10. Palm Oil	$0.4bn	1.3%

89. Source: https://www.dnp.gov.co/programas/inversiones-y-finanzas-publicas/Paginas/Sistema-General-de-Regal%C3%ADas---SGR.aspx
90. Sources: various firm-level Sustainability Reports, mining censuses and DANE's annual national employment and income survey, the Gran Encuesta Integrada de Hogares (GEIH, https://microdatos.dane.gov.co/index.php/catalog/599 for 2019). Further details are provided in specific references in section 4.
91. Source: various versions of the Marco Fiscal de Mediano Plazo, in particular, the 2021 version (https://www.minhacienda.gov.co/webcenter/ShowProperty?nodeId=%2FConexionContent%2FWCC_CLUSTER-165808%2F%2FidcPrimaryFile&revision=latestreleased)
92. This scenario was constructed from variety of sources, including the International Energy Agency's Stated Policies Scenario, publicly available from Ibid. International Energy Agency (2021)
93. This means that the numbers would be more extreme in a 1.5C scenario, the bottom end of the Paris Agreement target range.
94. This scenario was constructed from a wide variety of sources, including the International Energy Agency's Sustainable Development Scenario, publicly available from Ibid. International Energy Agency (2021).
95. See: MIT OEC: https://oec.world/en/profile/country/col, compiled from DANE

The key inputs to the global scenarios used in this analysis are set out in table 6 below:

Table 6: **Summary of climate transition scenario information, including core demand data**

Model	Demand data	Long run demand vs. BAU	Transition risk trajectory
Crude oil and oil products	Global crude oil demand time series, based on crude demand requirements for global refining, required to fulfil global product demand. Global oil product demand time series, based on oil products demand forecasts across all key consumer segments	Lower	Downside
Copper	Global copper demand time series, based on copper demand forecasts across all key consumer segments, across scenarios and beholden to circular economy principles	Higher	Upside
Steel	Global and regional demand forecasts based on material efficiency and circular economy principles for steel use in construction, in a transition	Lower	Upside
Iron Ore	Global and regional demand forecasts based on material efficiency and circular economy principles for steel use in construction, in a transition	Lower for fines, limited change for lump and higher for pellets	Downside for fines, limited change for lump and upside for pellets
Metallurgical coal and coke (seaborne)	Import demand time series, derived from recent historic trade, and expected regional decarbonisation trends in BF-BOF processes	Lower	Downside
Thermal coal (seaborne)	Import demand time series (mtce) for major importing countries and regions. Derived from analysis of future demand and local production.	Lower	Downside
Liquefied natural gas	Global and regional LNG import time series. Derived from regional gas consumption forecasts and domestic and regional pipeline gas production	Lower	Downside

We set some of the detail underpinning these scenarios in chapter 3 as part of each sectoral description of Colombia's climate transition risk exposure.

2.4.3.2. The impact of global scenarios on domestic prices

The dynamics described above will directly impact the revenues earned by Colombian exporters through the impact on prices and potentially also through the impact on volumes. However, these dynamics will also have significant impact on domestic prices in Colombia.

The degree to which domestic wholesale prices will be impacted by external transition risk will depend principally on how well integrated the domestic market is with international trade.

We identified two basic paradigms for the linkages with international trade:

- Prices for commodities and products where Colombia is self-sufficient, and which are mostly or largely insulated from international dynamics, due to technical, transport and infrastructure constraints. These products are not traded on liquid domestic markets, rather subject to bilateral negotiation between buyers and sellers. Firms operating in these markets are largely insulated from external transition risk.
- Prices for commodities and product where Colombia either does not produce sufficient volumes to meet domestic demand or where excess production is exported. In the first case, wholesale prices are often set at "import parity", with Colombian producers receiving the amount that it would cost to import the product. In the second case, with "export parity" pricing, Colombian producers would receive a price equal to that, which it would receive on the export market, including the cost of transporting the product to port.

The pricing mechanisms used in our analysis, are set out in table 7.

Table 7: **Linkage of Colombian domestic prices to international prices, by sector**

Commodity (all for domestic consumption)	Level of linkage	Pricing basis	Description
Thermal coal	Limited	Bilateral contracts	Thermal coal consumed in Colombian power stations and industrial facilities is not typically exported, due to high transport costs and infrastructure capacity constraints. Pricing is therefore usually a function of contracts negotiated between producers and power stations over a range of tenors. The one exception is Norte de Santander, where domestic historically had more options to export[96]. The base price for royalties for domestic thermal coal are also calculated based on domestic price observations[97].
Metallurgical coal and coke	High	Export parity pricing	Metallurgical coal is principally exported as coke. Domestic consumption of coke is likely to be dominated, in the short term, by the Paz del Rio steel plant, which has integrated coking facilities. The base price for royalties for domestic metallurgical coal is set with reference to a weighted average of international prices and domestic price observations[98].
Steel	High	Import parity pricing	Colombia is a net importer of steel products, meaning that domestic prices for most products are mostly linked to import prices from international markets[99]

96. Exports from Norte de Santander through Venezuelan ports have been essentially stopped due to political turbulence in Venezuela and around the Colombia-Venezuela border. Source: Wood Mackenzie
97. Historic information on royalty calculations is taken from the resolutions published quarterly by UPME: https://www1.upme.gov.co/simco/PromocionSector/Normatividad/Paginas/Resoluciones-de-Liquidacion-de-regalias.aspx
98. See previous footnote
99 For information on historic steel production and pricing (https://www.dane.gov.co/index.php/estadisticas-por-tema/industria/encuesta-anual-manufacturera-enam)

Commodity (all for domestic consumption)	Level of linkage	Pricing basis	Description
Crude oil	High	Export parity pricing	Colombia is a net exporter of crude oil, meaning that prices of crude sold to local refineries are mostly linked to the international market.
Oil products	High	Mix of import and export parity	The price basis has recently been switched from export parity to import parity pricing for gasoline, diesel and jet fuel has been implemented, partly with the aim of reducing pressure on Colombia's fuel price stabilisation fund.[100]
Natural gas	Mixed	Current bilateral contracts to be replaced by import parity[101]	When gas usage began in Colombia, domestic gas prices were decoupled from international markets as utilities and domestic suppliers operated based on bilateral contracts[102]. Colombia started to import LNG in 2016 to meet growing demand. However, with the majority of volumes covered by contracts and a limited inland pipeline network preventing LNG from being sold inland, the risk of managing international prices was limited As imports continue to increase and with plans to expand the inland pipeline network, we expect increasing linkage of Colombian wholesale gas prices with international markets, unless a decline in domestic demand or a sharp rise in domestic supply can once again ensure that Colombian production is sufficient to meet demand.
Cement and concrete	Limited	Bilateral contracts	Cement and concrete are rarely traded significant distances as transport costs are typically high due to the weight of the product. Prices are therefore set by local supply and demand negotiations.
Electricity	Limited but could grow	Market and contract-based revenue mechanisms and reliability charges	Wholesale electricity prices have limited linkage to international markets, given the current insulation of coal and gas prices from those markets. However, this could increase over time, depending on the future pricing of natural gas.
Hydrogen	Limited	Intra-group transfer	Currently, hydrogen is only produced in Colombia for use in oil refineries. This is produced and consumed within the Ecopetrol group, we assume at cost.

In Colombia, price regulation, policy and import tariffs also have an impact on the extent to which changes in international prices impact the final consumer. For example, our analysis accounts for the impact of the FEPC in stabilising retail gasoline and diesel prices against international market fluctuations. Retail natural gas and electricity pricing operate in systems where customer groups with greater ability to pay partially cross-subsidise those with limited ability to pay, supported by central public subsidy. These mechanisms do not influence the level of external transition risk that Colombia will bear, rather it influences the distribution of that risk within the economy.

100. Summary information about the fund – the Fondo de Estabilización de Precios de los Combustibles (FEPC) – is available here: https://www.minhacienda.gov.co/webcenter/ShowProperty?nodeId=%2FConexionContent%2FWCC_CLUSTER-192817%2F%2FidcPrimaryFile&revision=latestreleased#:~:text=Es%20el%20fondo%20que%20se,productores%20e%20importadores%20dicha%20diferencia.
101. This assumes that additional Colombian production from new offshore finds is not enough to restore Colombia to self-sufficiency, a prudent assumption, given the early stage of some of the findings
102. Source: https://www.fitchratings.com/research/corporate-finance/colombian-gas-utilities-are-insulated-from-high-international-prices-02-05-2022

2.4.3.3. Domestic scenarios

Most of Colombia's recent transition policy documents are focused on domestic decarbonisation pathways and growing green financing, rather than mitigating external transition risk. The E2050 vision authors make explicit their assumption of only a limited impact of the transition on oil, coal and coke exports and hence implicitly assume that "the exports from these sectors remain stable"[103], supporting Colombian economic growth throughout the transition. The Plan Energetico Nacional (PEN) expresses some concern about long-run declines in global demand for oil and coal[104], but also expresses optimism about the promise of developing biofuels production for future export, a product currently mostly made using ethanol and palm oil[105].

To determine appropriate domestic scenarios, we reviewed key policies, as set out in table 8:

Colombia's NDC, Energy Transition CONPES and E2050 are structured mostly as strategy/vision documents, which set the framework for a forthcoming series of policy papers, laws and regulations, as summarised in table 1, which are designed to translate objectives into practical implementation actions. We were not yet able to discern any detailed sector-level implementation guidance and modelling in line with Colombia's E2050 vision that might form the basis of an internally consistent WB2C scenario. We therefore decided to focus the domestic part of this study on the potential costs, benefits, risks, and uncertainties associated with different technological decarbonisation paradigms.

While the Petro administration has signally a willingness to use the tax system as a means to incentivise decarbonisation in electricity and industrial sectors[109] , significant uncertainty remains in relation to the planned speed of the Colombian transition and the policies that will be used to incentivise it. This uncertainty is perhaps the greatest source of domestic transition risk for Colombian stakeholders.

Table 8: **Non-exhaustive summary of key policy documents**

Policy plan	Publication date	Scope
NDC	2020	Economy-wide
E2050	2021	Economy-wide
Plan Nacional de Desarollo	2022/2023	Economy-wide
Reforma Tributaria	2022	Economy-wide
Estratégia Nacional de Movilidad (ENME)[106]	2019	Transport. Focussed mainly on short-term time horizons, with some longer-term (2050) recommendations
CONPES de Transición Energética	March 2022	Electricity, mining, hydrocarbons, and transport sectors. Less focus on industry. Focus on period to 2030
Plan Integral de Gestión de Cambio Climatico del sector Minero-Energético (PIGCCme)[107]	November 2021	Full energy and mineral complex. Longer-term (2050 vision)
Plan Energético Nacional (PEN)	2020	Detailed technoeconomic modelling, particularly of energy supply and demand. Time horizon to 2050
Hoja de Ruta del Hidrógeno	September 2021	Hydrogen – supply, demand, and infrastructure. Time horizon to 2050
Hoja de Ruta de la Energía Eólica Costa afuera en Colombia	February 2022	Offshore wind – technical and practical study. Time horizon to 2050
Plan Maestro Ferroviario[108]	April 2021	Freight railway reactivation plan.

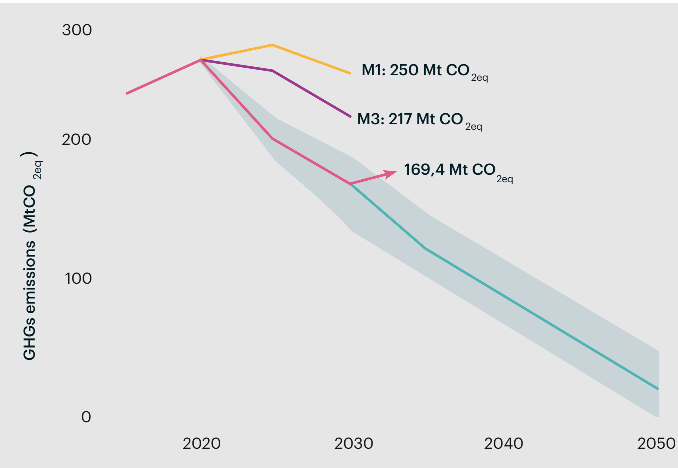
103. Source: https://e2050colombia.com/wp-content/uploads/2021/11/2050_Libro_final_digital_baja_compressed.pdf (page 98)
104. See UPME (2020), page 113
105. The Balance Energético Colombiano (BECO) was a key source of information about the historic use of energy resources in different real economy sectors. The database can be accessed at: https://www1.upme.gov.co/DemandayEficiencia/Paginas/BECOEnergetico.aspx
106. Source: https://www1.upme.gov.co/DemandaEnergetica/ENME.pdf
107. Source: https://www.minenergia.gov.co/documents/6393/PIGCCme_2050_vf.pdf
108. Source: https://colaboracion.dnp.gov.co/CDT/Prensa/Plan-Maestro-Ferroviario.pdf
109. The Reforma Tributaria extends the scope of the carbon tax to include coal. Source: https://www.minhacienda.gov.co/webcenter/ShowProperty?nodeId=%2FConexionContent%2FWCC_CLUSTER-200757%2F%2FidcPrimaryFile&revision=latestreleased (Accessed 13 March 2023)

2.4.3.4. The risks arising from Colombia's current policy reliance on AFOLU sector decarbonisation

Colombia's domestic decarbonisation planning to-date (which has resulted in the NDC and E2050 visions) have been typically underpinned by assessments of technical feasibility and economic analyses (considering the cost and value of different policy options and the resulting job loss/creation) using a range of Colombian government in-house economic models (such as the MEG4C general equilibrium model). Colombia has also drawn on international expertise, in particular, from the Deep Decarbonisation Pathways Latin America (DDP LAC) programme. The DDP LAC analysis, originally developed to support the NDC update, used a Colombia-conditioned "integrated assessment model"[110] to explore the economic cost of a range of future emissions reduction pathways.

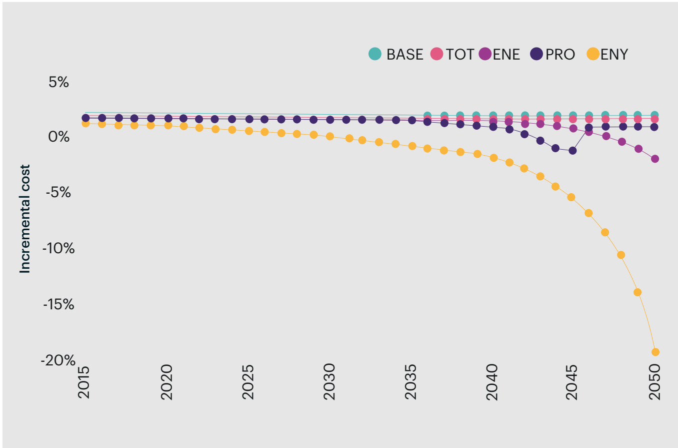
The E2050 builds from the foundation of the analysis underpinning the NDC, with a vision of accelerated deep decarbonisation beginning in the 2030s (figure 2).

Figure 2: **Colombia's target decarbonisation trajectory (E2050)**[111]



According to the analysis underpinning the E2050, in most scenarios, the incremental cost of meeting policy goals would be limited (as shown in figure 3 below). And Colombia's physical risk exposure associated with the world failing to meet its decarbonisation targets would be far more significant. The arguments in favour of deep decarbonisation are clearly presented. However, it is not possible to determine with any precision from these documents the intended relative share and speed of decarbonisation between different real economy sectors.

Figure 3: **Incremental costs of meeting Colombia's E2050 policy goals, in a range of scenarios (E2050)**



What does seem clear is that Colombia's decarbonisation ambitions will stand or fall on the extent to which it is successful in reducing emissions from land use (AFOLU sectors). While gross[112] annual AFOLU emissions fell by around 18% between 1990 and 2014[113], they have risen sharply recent years, as shown in table 9. AFOLU sectors consistently remain the largest sources of Colombia's greenhouse gas emissions.

Table 9: **Land use share of Colombia's emissions historically (mt CO2e unless otherwise stated)**[114]

	1990	1995	2000	2005	2010	2014	2018
Total GHG emissions	220.3	236.4	223.9	218.1	230.2	236.4	279.2
Gross AFOLU	163.7	167.7	153.7	144.1	142.0	140.6	179.1
AFOLU absorption	-5.0	-5.8	-7.5	-11.0	-17.1	-21.8	-23.8
Net AFOLU	158.7	161.9	146.2	133.1	114.0	118.8	155.3
AFOLU share of total	72.0%	68.5%	65.3%	61.0%	54.3%	50.3%	55.6%

110.
111. The basis for the Colombia analysis is the "Global Change Assessment Model" or "GCAM". More information is shown here: http://www.globalchange.umd.edu/gcam/
112. Source: E2050
113. "Gross" deforestation, i.e. before netting off new tree planting / afforestation
114. Of the net 118.8 mtCO2e gross emissions in 2014 from AFOLU sectors, the largest contributors were approximately 40mt relating to grasslands, 38mt relating to cattle raising and 28mt related to forest land. By 2018, total AFOLU emissions were up by 31% compared to 2014. Grassland emissions rose to 58mt (up 45%), cattle raising emissions rose to 45mt (up 18%) and forest emissions rose to 40mt (up 43%).

Table 10: **Mining and energy sector emissions scenarios (millions of tonnes of CO2 equivalent)**

Scenario	2014	2020	2030	2040	2050
PEN *Actualización*	73	62	75	82	90
PEN *Modernización*	73	62	71	73	75
PEN *Inflexión*	73	62	69	68	69
PEN *Disrupción*	73	62	59	55	53
E2050 *Carbono neutralidad*	73	62	64	35	12

Despite the limited historical success in reducing emissions in AFOLU sectors, Colombia's NDC assumes a far more significant acceleration of emissions reduction between now and 2030 than in any other economic sector. Colombia has pledged to reach "net zero deforestation" by 2030, meaning that CO2 absorptions from newly planted trees and restored ecosystems would at least offset the emissions from deforestation[115]. To be successful, Colombia would by 2030, need reduce AFOLU emissions on a net basis by around 40mt[116] or 26% of the 2018 total. International non-profit organisation Climate Action Tracker[117] estimates that Colombia relies on "land-based mitigation measures for approximately 70% of the revised [NDC] target".

One of the reasons why meeting the 2030 deforestation target is likely to be extremely challenging is that the causes of deforestation – as identified by the government[118] – are multiple and complex to resolve. These include: turning forest into grassland for the purpose of staking claims over the land; an inconsistent land registration system; bad cattle farming practices; poorly planned new transport infrastructure; growth of coca and other illegal crop plantations; growth of illegal mines and other extractive industries; illegal logging and the expansion of agriculture into areas where farming is not permitted, including conservation areas.

The practical challenges relating to AFOLU sectors decarbonisation could be both a source of risk and opportunity in Colombia's mining, energy, and industrial sectors. In the event of an expected shortfall in AFOLU decarbonisation compared with plan, a future Colombian government may seek to drive accelerated decarbonisation from mining and energy.

However, just as with AFOLU, there remains some dissonance between the policy vision, as set out in the NDC and E2050 and sector-level implementation plans[119]. In the PEN, the most aggressive decarbonisation scenario envisaged (the scenario named Disrupción) shows greenhouse gas emissions in the mining and energy sector (without accounting for fugitive emissions) only 15% lower in 2050 than in 2020. By contrast, as illustrated in table 10, the E2050 vision implies an 81% reduction compared with 2020.

One reason why the PEN's *Disrupción* scenario has such relatively high emissions in 2050 compared with the E2050 is partly because the PEN assumes limited decarbonisation in Colombian industry (the PEN authors assume that 41% of final energy consumption is fuelled by natural gas, coal, coke and oil-based fuels) and because the scenario assumes the continued presence of coal- and gas-fired power to 2050, representing 9% of installed capacity as at 2050.

The PEN authors could do more to clarify why they chose a scenario containing such a continued high share of fossil fuels in the most ambitious decarbonisation scenario. Recent academic studies in Colombia and the US[120] have illustrated the technical potential of zero carbon electricity systems, highlighting the need to develop appropriate flexible "clean firm" capacity to supplement fluctuations in wind, solar and hydro supply (and in the case of Colombia, to provide back-up in El Niño years), which, in Colombia, could potentially be provided by clean hydrogen or biomass-fired plants. Significant progress has also been made in recent years in developing technoeconomic pathways for deep decarbonisation in "hard-to-abate" sectors, such as iron and steel, cement, chemicals, freight transport, marine and aviation fuels[121] . The technological challenges in decarbonising industrial sectors requiring low temperature (<250C) heat (key Colombian sectors in this category include sugar refining, pulp and paper and textiles) are easier to overcome (with electricity, hydrogen, and biomass all as potential energy sources), though the practical challenges for dispersed Colombian industries[122] are not to be underestimated. The long capital turnover cycles associated with most industrial sectors intensify these challenges, as new investments in emissions-intensive technology will mostly not be fully amortised by 2050.

115. All emissions figures are taken from Colombia's Biennial Update Reporting to the UNFCCC. See: https://unfccc.int/sites/default/files/resource/BUR3%20-%20COLOMBIA.pdf
116. The government's "net zero" target means reducing "gross" deforestation to 50,000 hectares per year, per Climate Action Tracker Analysis: https://climateactiontracker.org/countries/colombia/policies-action/#:~:text=Colombia%20had%20previously%20set%20a,an%20overall%20weaker%20deforestation%20reduction
117. This is the represents the amount of forest emissions, net of absorptions in 2018. These need to be reduced to zero by 2030 in order to meet the target
118. Ibid, Climate Action Tracker
119. http://www.ideam.gov.co/documents/10182/113437783/Presentacion_Deforestacion2020_SMByC-IDEAM.pdf/8ea7473e-3393-4942-8b75-88967ac12a19
120. See UPME (2020)
121. One of the most detailed deep decarbonisation plans for the USA is available here: https://energyinnovation.org/wp-content/uploads/2020/09/Pathways-to-100-Zero-Carbon-Power-by-2035-Without-Increasing-Customer-Costs.pdf. Clean firm capacity is a key part of this
122. The Energy Transitions Commission and related organisation, Mission Possible Partnership, have published detailed research on decarbonisation options and costs for hard-to-abate sectors which are publicly available at: https://www.energy-transitions.org/sector-decarbonisation/ and https://missionpossiblepartnership.org/

2.4.3.5. Sketching out potential Colombian domestic climate transition scenarios

Sketching out the parameters of a Colombian baseline scenario is important for this work as many Colombian domestic assets are affected external climate transition risk (see section 2.4.3.2).

This is much more straightforward than constructing a deep decarbonisation scenario in line with the E2050 vision. Such a scenario – designed to reflect expectations already factored into markets - would be based on policies already well advanced in their implementation, but not those where there is significant uncertainty about policy choice[123]. It would not necessarily assume that Colombia will meet its NDC pledge, nor would it seem likely to resemble the NDC reference scenario whose relevance appears to be limited since it was proposed before the COVID-19 pandemic and war in Ukraine.

A core assumption of such a baseline scenario is that Colombian policymakers seek to achieve their NDC goals without major structural change to Colombia's economic model and otherwise focus their decarbonisation efforts on deforestation and efforts to scale up the integration of non-hydro renewable power generation (the latter of which may also facilitate the growth of a domestic hydrogen industry).

In this scenario, demand for materials such as concrete, steel and glass – a key driver of energy demand – remain strongly correlated to GDP growth over this period, putting upward pressure on energy consumption and hence emissions relating to the mining, energy, and industrial sectors. Set against this are nascent trends towards the reduction in carbon intensity of that energy demand, namely, reduction in the carbon intensity of electricity supply, growth of investment in public transport and industrial energy efficiency as well as the increasing take-up of electric vehicles and interest in circular business models. We assume, as per the recent Hoja de Ruta for clean hydrogen[124], that sufficient "green hydrogen" may become available by the 2030 to replace existing use of "grey hydrogen" in refineries and fertiliser production, but not in sufficient quantities to enable export or incremental decarbonisation potential in transport and industry.

Between 2030 and 2050, the continuation of existing trends would result in continued gradual decarbonisation of electricity supply and growth in the market share of electrified transport but no major new decarbonisation efforts in industrial, residential, or commercial use. As illustrated in table 11, this means the baseline shows emissions in 2030 in line with the PEN's *Actualización* scenario, with emissions in 2050 closer to the PEN's *Inflexión* scenario. In both years, the baseline shows a significant gap to the trajectory implied in the E2050, reflecting the fact that Colombia has not yet implemented sufficient actions to drive deep decarbonisation in line with the aims of the E2050.

Underlying the above, is a series of industry-specific trajectories and assumptions, which drive our scenario for the key energy sources used to construct this baseline scenario, as set out in table 12.

Table 11: **Key parameters of this project's Colombian baseline scenario to 2050 for mining and energy sectors vs. third party scenarios (millions of tonnes of CO2 equivalent unless otherwise stated)**

	2014	2030	2040	2050
Third-party reference scenarios				
NDC reference scenario	73	90[125]		
PEN Actualización	73	75	82	90
PEN Disrupción	73	59	55	53
E2050	73	64	35	12
Colombia BAU scenario				
Electricity generation	12	7	6	5
Transport	29	38	36	31
Coke production	9	10	10	10
Other industry (energy usage)	16	16	17	17
Residential and commercial	7	7	8	9
Total – PEN scope	**73**	**78**	**77**	**72**
Fugitive emissions	7	4	2	2
Industrial process emissions	8	8	8	8
Total – all mining, energy, and industrial emissions	**88**	**90**	**87**	**82**

123. We estimate that Colombia has over 1,000 brickmaking kilns (https://www.ccacoalition.org/en/activity/transformation-bricks-sector-colombia-successful-intervention-model) and more than 500 glass-making facilities (https://www.volza.com/suppliers-colombia/colombia-exporters-suppliers-of-glass).
124. The Energy Transition CONPES is available here: https://colaboracion.dnp.gov.co/CDT/Conpes/Econ%C3%B3micos/4075.pdf
125. The Hoja de ruta del hidrogeno is available here: https://www.minenergia.gov.co/documents/10192/24309272/Hoja+Ruta+Hidrogeno+Colombia_2810.pdf;jsessionid=0NAJdO0gm5QBqOyq47qgr9nL.portal2#:~:text=La%20Hoja%20de%20Ruta%20del,Acuerdo%20de%20Par%C3%ADs%20del%202015.

Table 12: **Macro and demand variables in Colombian baseline scenario**

		2014	2030	2040	2050
GDP growth	%	4.5	3.5	3.5	3.5
Long steel product demand	Mt	2.2	3.4	4.8	6.8
Thermal coal	Mt	5.5	6.0	5.0	5.0
Met coal	Mt	3.7	4.0	4.0	4.0
Diesel	Kbbl/day	142	142	159	177
Gasoline	Kbbl/day	110	149	167	185
LPG	Kbbl/day	19	22	25	28
Natural gas	Mt	10	9	9	10

Beyond the GCAM model used to support the construction of the E2050 trajectory, we are not aware of any other model which sets out a lower carbon long-term Colombian trajectory that is consistent with the E2050 trajectory. With limited access to asset-level data[126], the team generated top-down an alternative lower carbon scenario, which we used to consider the relative costs, benefits, risks, and uncertainties relating to different decarbonisation pathways (as set out in chapter 5). This is presented below for comparison:

Table 13: **Alternative accelerated decarbonisation scenario for mining and energy sectors to 2050 (millions of tonnes of CO2 equivalent unless otherwise stated)**

	2014	2030	2040	2050
Baseline	73	78	77	72
E2050	73	64	35	12
Alternative scenario				
Electricity generation	12	7	1	0
Transport	29	34	19	8
Coke production	9	10	5	0
Other industry (energy usage)	16	12	9	2
Residential and commercial	7	6	4	2
Total – PEN scope	**73**	**69**	**38**	**14**
Fugitive emissions	7	1	0	0
Industrial process emissions	8	7	6	1
Total – all mining, energy, and industrial emissions	**88**	**77**	**44**	**15**

126. This is figure is the authors' estimation of Colombia's expected greenhouse gas emissions in 2030 in the reference scenario from Colombia's Nationally Determined Contribution (NDC), based on a graph. The document is available from: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Colombia%20First/NDC%20actualizada%20de%20Colombia.pdf

This scenario differs from the baseline scenario in four important ways. Firstly, it assumes that a completely emissions-free electricity grid will be technically possible and practically achievable in Colombia, given Colombia's high share of hydro resources and technical progress being made with high variable renewable energy systems and "clean firm" backup generation. Secondly, it assumes that policies are introduced to accelerate decarbonisation of Colombian transport and industrial sectors. Thirdly, it assumes the impact of external climate transition risk, which largely curtails Colombia's thermal coal, metallurgical coke, and crude oil production by 2050. Fourthly, it assumes the successful deployment of CCUS technologies, focused in industrial sectors.

While the above scenario cannot necessarily be considered an internally consistent Colombian scenario, each of the sectoral pathways are based on recent Colombian or global reach, detail provided in the PEN for the power sector[127], a recent UPME-commissioned-study about deep decarbonisation in transport[128], global decarbonisation pathways for hard-to-abate industrial sectors and references from the E2050 document. One of the key recommendations from this report is the need to expedite the construction and publication the of transparent sector-level decarbonisation pathways that will be required to implement the E2050.

2.5 Adding value to other research on climate transition risk in the Colombian context

This paper adds to the growing literature and initiatives aimed at defining, measuring, and managing climate transition risk in the Colombian context.

Initially, Colombian efforts to measure climate transition risk (as opposed to defining Colombian decarbonisation pathways, discussed in section 2.4) were concentrated in the financial sector and largely led by the SFC. Rather than moving quickly to implement climate risk stress tests or to integrate climate risks into core supervisory activities, the SFC recognised the initial limited awareness within the Colombian financial sector of climate change, climate-related financial risks and the emerging tools for measuring and managing them. It has then supported and participated in a range of targeted training efforts led by Universidad de Los Andes' Centro de Finanzas Sostenibiles (CFS), with the aim to build the capacity required to respond to more sophisticated and onerous regulatory requirements that might be introduced in future years.

In parallel, the SFC has been working to understand the current climate transition risk exposures of individual Colombian financial institutions and working with BanRep to understand the implications of poorly managed climate-related financial risk (including physical risk) for financial stability. Meanwhile, BanRep has pursued detailed analysis using its own models to assess the macroeconomic impacts of climate change and unmitigated climate transition risks[129]. Both institutions have pointed out that effective management of climate-related risks within the financial system, within monetary and economic policy, will be critical for the ability of Colombia to make the level of investment required to implement mitigation and adaptation goals at reasonable cost. Furthermore, the implementation of an effective and transparent climate risk regulation architecture (including other mechanisms, such as the green taxonomy) will be an important part of futureproofing Colombia against increasingly stringent ESG-related and climate risk-related requirements from private sector international investors. Access to new innovative and concessional climate finance facilities (e.g., the Just Energy Transition Partnership in South Africa) may also become increasingly dependent on the ability of countries to demonstrate effective governance of climate risks.

At the level of Colombian policymaking, both DNP and MHCP have taken important steps to start to consider the impact of climate transition risk on the Colombian economy and public finances, using existing general equilibrium models, such as MEG4C and more innovative approaches, such the GEMMES[130] concept developed by AFD. Amongst other things, the GEMMES model will enable Colombian policymakers to consider implications of Colombia's external position that are not possible with MEG4C. These models may not only help Colombia assess the relative costs and financing implications of different Colombian transition paths, but also help Colombia assess the viability of potential future alternative economic models.

We see potential of this research to provide additional support to SFC, BanRep, DNP, MHCP and Colombian policymakers in deepening their understanding of Colombia's climate transition risk exposure and the options available for mitigating them. By developing global and Colombia-specific scenarios; conducting micro-level analyses of sectors, firms; and regions; and mapping climate transition risk allocation and transmission channels, this work can help to refine the inputs to ongoing analyses (such as GEMMES) and add depth to the insights from previous analyses, including recent ones by international specialists 2 Degrees Investing Initiative (2DII), the World Bank (WB) and the International Monetary Fund (IMF).

127. The team did not have access to any asset- or firm-level data used in UPME's modelling. This data is proprietary to UPME
128. The PEN is publicly available at: https://www1.upme.gov.co/DemandayEficiencia/Paginas/PEN.aspx#:~:text=Plan%20Energ%C3%A9tico%20Nacional%20PEN%202020,los%20posibles%20caminos%20para%20alcanzarla.
129. The deep decarbonisation research on the transport sector commissioned by UPME is available at: https://www1.upme.gov.co/DemandayEficiencia/Documents/Informe_final_Ascenso_tecnologico.pdf
130. Source: https://investiga.banrep.gov.co/es/espe102

The PACTA[131] tool, which was developed by 2DII to assess "Paris-alignment" in financial institution equity and credit portfolios, measures firms against a scenario derived principally from the International Energy Agency's (IEA's) Sustainable Development Scenario (SDS)[132]. In practice, PACTA's sectoral pathways (such as for oil and gas, power generation etc.) are derived from global trajectories. This means that the same Paris-aligned scenario is imposed on any given sector is the same in every country, regardless of that country's climate transition policy (which influences the timing of changes in demand for energy-intensive goods) or the position of that country's commodity producing assets on global supply curves. In the oil sector, this would mean that the cheapest crude oil expected to be available on the global market (typically produced in Saudi Arabia) is treated in exactly the same way as the most expensive crude oil expected to be available on the global market (for example, US shale). The analysis set out in this paper can help to refine the assessment of Colombian financial institutions' Paris alignment, by considering the relative competitiveness of Colombian oil producing assets and the expected demand trajectory for liquid fuels in Colombia, as per Colombia's domestic transition plans.

The stress tests performed by the WB and IMF in relation to the Colombian banking sector take roughly similar approaches to simulate the impact of accelerated decarbonisation in the late 2020s. The WB analysis uses a sharply increasing carbon price between $64-$216 per tonne[133] to drive an analysis of the impact on value added in key real economy sectors and then uses the resulting macroeconomic impacts to estimate the potential change in non-performing loans and hence, capital ratios, for key banks. In the most severe scenario, where policies designed to drive NDC compliance are implemented over a two-year period, GDP in certain extractive industries declines by more than 50%, impacting non-performing loan rates by between 0.5% and 1.9%, depending on the loan categories. However, given that the current Colombian carbon tax of just over $5 / tonne for certain fuels[134] and the strong recent public opposition to a more modest proposed increase in carbon pricing[135], we expect that it will not be practically possible over the next ten years to extend the scope of carbon pricing across the economy as well as increasing the rate of the tax by more than 10-20x, as implied by the WB paper. A more feasible and cost-effective low carbon scenario might consider the use of carbon pricing as part of a portfolio of policy measures, which might would also likely have different distributional consequences, as explored in chapter 5 of this report.

An enhanced understanding and monitoring framework for the evolution of climate transition risk in the Colombian economy and its distribution within the Colombian financial system could help SFC, BanRep, and Colombian policymakers to effectively track the evolution of climate transition risk exposure in the Colombian financial system over time and the impact (positive or negative) that the changing strategies of financial sector firms are having on that exposure. The information could also support the SFC in providing appropriate scenario information to financial institutions that would help them manage their risks more effectively. It would also help BanRep develop its monetary policy response toolbox. Broader awareness and more robust risk management practice could then support the introduction of new regulatory tools, which help to accelerate the shift of Colombian capital from emissions-intensive to low carbon sectors at sufficient speed to help deliver the real economy transition envisaged by the E2050.

131. Details about AFD's GEMMES modelling approach can be found here: https://www.afd.fr/en/page-programme-de-recherche/gemmes-new-modelling-tool-incorporates-energy-transition
132. Stewardship of PACTA was transferred from 2 Degrees Investing Initiative to RMI (formerly Rocky Mountain Institute) in 2022. Details on the tool can be found at: https://www.transitionmonitor.com/
133. The SDS is typically described every year in the World Energy Outlook. The most recent one is available from here: https://www.iea.org/reports/world-energy-outlook-2021
134. See full report at: https://openknowledge.worldbank.org/bitstream/handle/10986/36586/Not-So-Magical-Realism-A-Climate-Stress-Test-of-the-Colombian-Banking-System.pdf?sequence=1&isAllowed=y
135. Unusually, compared with common international practice, the Colombian carbon tax is levied on fuel producers and importers, rather than consumers. Coal and coke are exempt. Natural gas is also excluded unless selling to refineries and the petrochemicals industry. Further detail is available at: https://www.ieta.org/resources/Resources/CarbonMarketBusinessBrief/CarbonMarketBusinessBriefColombia2020.pdf

3. Climate transition risk in Colombia

Key messages:

1. Across thermal coal, metallurgical coal and coke and the oil and gas value chains, Colombia faces $88 billion of downside risk (or 27% of 2019 GDP) from the global transition over the period from 2022 to 2050. $43 billion of this downside risk is in the thermal coal value chain, $41 billion in the oil value chain with the metallurgical coke and natural gas industries making up the rest.

2. Downside risk would manifest itself in a WB2C scenario (compared with a BAU scenario) principally through lower demand for Colombian exports and lower prices. Thermal coal exporters stand to face both lower demand and prices while oil and gas producers are more affected by price differentials. On the other hand, lower prices for liquid fuels and natural gas would be a gain to users of those fuels.

3. In a WB2C scenario, Colombian coal exports do not appear to be competitive in more resilient Asian markets because of shipping costs and distance. In this scenario, Colombian coal exports would largely cease by the early-to-mid 2030s.

4. Declining conventional production of oil and gas could make the country a net importer of hydrocarbons by the early-to-mid 2030s in both BAU and WB2C scenarios. Recent offshore gas finds do not seem large enough or advanced enough to change these dynamics.

5. Most new major investments in production and infrastructure capacity face downside risk on top of the $88 billion, even in the event of prolonged sanctions on Russian exports

3.1 Introduction

This chapter sets out the results of our analysis about Colombia's exposure to downside risk from the global transition. This is the risk that it is most important for Colombian policymakers to identify, measure, and manage because it is outside of the country's control and likely to be subject to increased volatility as geopolitical tensions associated with the global transition intensify. This external risk is concentrated in a relatively small number of economic sectors, both where demand for Colombia's exports would change in a WB2C scenario and where changes in international prices would affect Colombian domestic prices. For some sectors – notably crude oil extraction – Colombia could also face a paradigm shift, from being a net exporter to a net importer.

This chapter sets out the results of the analysis for each of these sectors in turn, before summarising the potential combined impact on Colombia's external balance. Each section includes a summary of the global transition dynamics at play; the mechanics by which those dynamics could impact the cash flows of Colombian assets ("**drivers**"); asset- and region-level detail about differential exposures; a review of the knock-on implications for core infrastructure and a review of the likely exposure of material parts of the value chain.

3.2 External climate transition risk quantification

Our research has shown that a global low carbon transition will cause fundamental shifts in global demand and prices for most of the world's largest internationally traded commodity markets. Oil, natural gas, and coal producers (both metallurgical and thermal) will experience lower global prices in a WB2C scenario than in a BAU scenario while internationally traded industrial fuels and key inputs, such as liquid fuels and coke, face a dual challenge from changes in industrial processes and the increasing investor pressure on many companies to reduce their carbon footprints at not only scope 1 and 2 levels, but also scope 3[136]. This will mean that, over 2022-2050, these real economy sectors are likely to experience lower revenues in a WB2C scenario, than in a BAU scenario[137].

136. See https://www.ft.com/content/218c0354-51fa-4b18-a940-137de7e3b3de for details about opposition to the 2020 tax reform
137. The EU is leading the way globally around the "greening" and greater sustainability of supply chains, particularly around "critical" minerals and will likely hope to export its regulatory standards to other countries through trade deals. This regulatory pressure is a driver of increased investor interest in carbon footprinting of supply chains. For one example, in graphite, see: https://www.innovationnewsnetwork.com/graphite-and-the-green-energy-transition/12295/

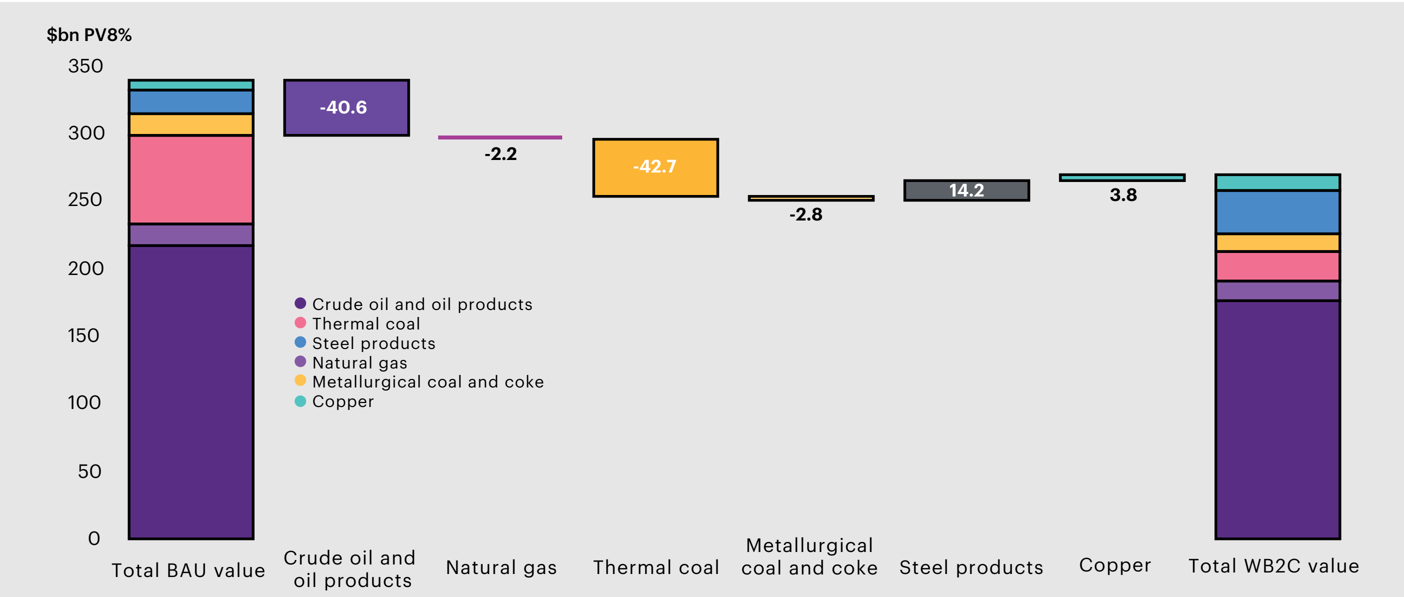
Our focus on the sectors set out in this chapter does not mean that other export sectors will not face climate transition downside risk. Supplementary research could usefully add to the insights set out in this paper to help understand the impact of other key economic variable that could change Colombia's economic competitiveness in a global transition across all trade sectors, including shipping costs and carbon border adjustments. Except for steel[138], this chapter does not include analysis of existing, nascent (for example, copper) and potential new sectors whose value would likely grow in a WB2C scenario. The potential of these sectors is discussed in chapter 5, but their separate treatment is deliberate, given that Colombia cannot expect these upsides to neatly offset the downsides set out in this chapter in either time, location, or distribution.

Over 2022 to 2050, Colombia faces around **$88 billion** of external climate transition downside risk (or 27% of 2019 GDP). This large economic and financial risk is mostly concentrated in thermal coal ($43 billion) and the oil value chain ($41 billion), with the natural gas value chain facing a much smaller exposure ($2.2 billion). In addition, we have estimated a further $2.8 billion relates to metallurgical coke, connected with structural changes in the steel industry that may increase the value of Colombia's steel plants in the short term[139].

To an extent, these numbers represent a "worst case scenario" as they do not incorporate any action to mitigate the risks by applying the products to sectors which may be more resilient to the transition[141]. These options are considered in chapter 4. However, in important other respects, these figures are likely to represent an underestimate of the downside risk that the country faces, given that our scenarios imply an "orderly" global transition and therefore smooth out the increasing volatility likely to arise, particularly as demand in global oil markets starts to contract.

Of the sectors reviewed, thermal coal clearly faces a much greater downside, relative to its BAU value. In a WB2C scenario, the export thermal coal industry would be worth 65% less, while total downside risk across the oil value chain amounts only to 19% of BAU value (upstream oil faces a 27% downside).

Figure 4: **Climate transition risk by sector**[140]



138. The increasingly "disorderly" nature of the global transition may mean an increase in volatility of cash flows, particularly in the oil sector
139. We include steel in a chapter that is generally focussed on downsides because existing Colombian steel producers would be affected by changing global markets. By contrast, we treat copper and other potential new growth sectors separately in chapter 5.
140. The costs of decarbonising Colombia's steel production may arise after these short-term gains and are likely to result in offsetting downside risk (see chapter 5)
141. We use a common discount rate across all the analysis in the report at – 8% being an estimate of the historic weighted cost of capital (WACC) for energy infrastructure sectors. In reality, this figure varies by company and can go up and down in response to changes in the economic cycle. Changes in the financial sector in response to climate (whether branded as "ESG" or related to climate risk) could also change the relative costs of capital of lower and higher emissions businesses over time, although estimating this based on fundamentally is difficult given that it is partly driven by a paradigm shift in investor behaviours. Keeping a common discount rate in this analysis is also helpful in practice, by changing only a small number of variables in each scenario, it is easier to isolate the impact of climate transition risk in particular.

3.2.1 Thermal coal

3.2.1.1. Global transition dynamics for thermal coal markets

Thermal coal is primarily used in power stations to produce electricity but is also often used in cement production and certain other industrial processes. Given that thermal coal is the most carbon intensive fuel currently used in power generation and new wind and solar power installations are now cheaper on a lifetime cost basis than the operating cost of most existing coal fired power stations (let alone new coal fired power stations)[142], thermal coal is the commodity most at risk of displacement as the global transition accelerates. Seaborne thermal coal is particularly at risk, as we expect major importers, such as China and India, to seek to protect their large domestic coal mining industries for as long as they can, cutting imports earlier[143].

On a global basis, demand for thermal coal has already peaked – the only question now is how fast it will fall. As illustrated in table 14, this fall is much faster in our WB2C scenario than in the BAU scenario.

Table 14: **Seaborne thermal coal demand scenarios (global)**[144]

		2019	2025	2030	2035	2040	2050
BAU	Mt	719	745	741	722	708	627
WB2C	Mt	719	617	451	355	229	0

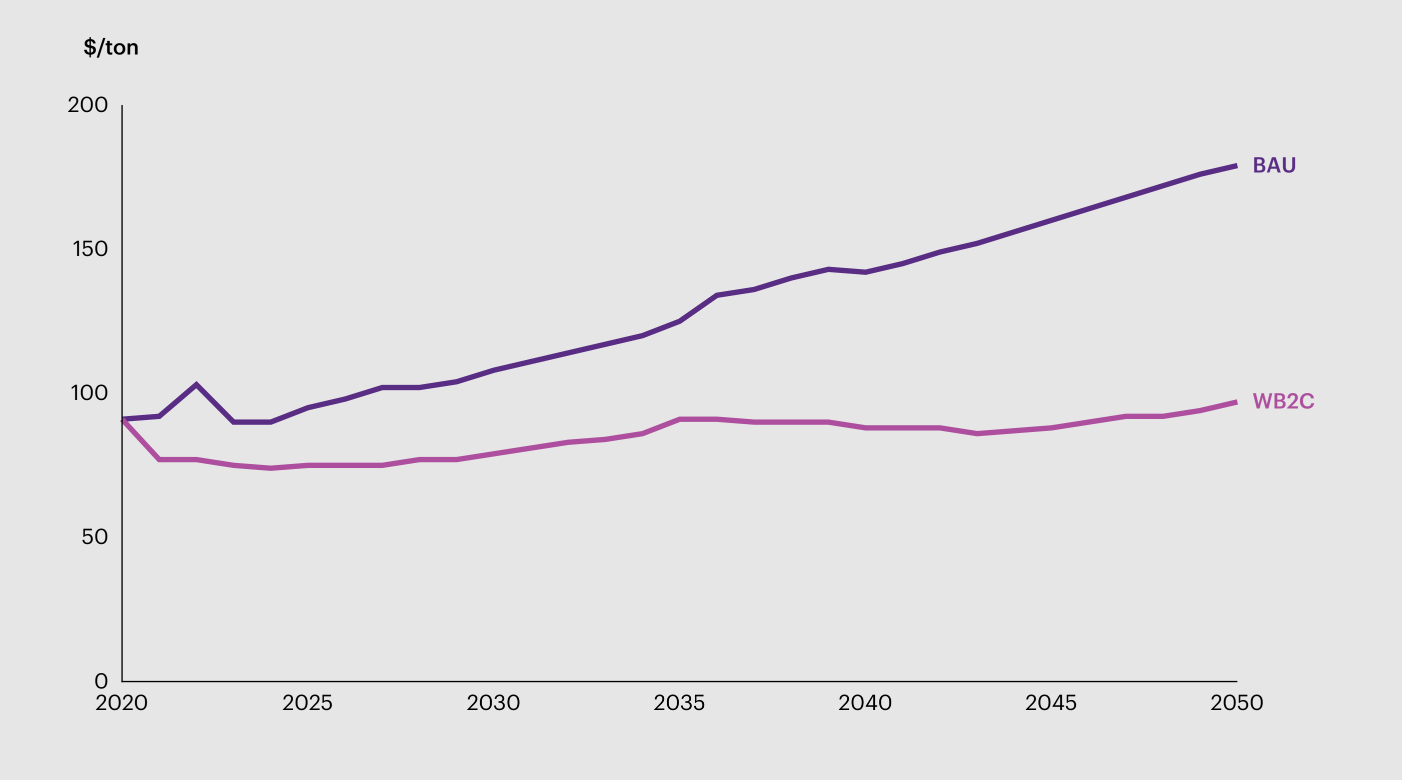
In the WB2C scenario, the only region without major immediate demand reductions into the 2030s is South-East Asia, as illustrated in table 15. In this region, demand does not increase significantly from current demand, reflecting the assumption that no new coal fired power stations would be built beyond those currently in construction[145].

Table 15: **Seaborne thermal coal demand in a WB2C by region**[146]

		2019	2025	2030	2035	2040	2050
China	Mtce[147]	137	230	189	128	35	0
India	Mtce	109	65	48	29	10	0
Japan and Korea	Mtce	205	123	41	32	23	0
South-East Asia	Mtce	59	67	72	71	70	0
Other Asia	Mtce	51	41	31	30	29	0
Turkey, Israel, Middle East and non-EU Europe	Mtce	45	44	35	29	23	0
EU	Mtce	81	17	10	8	6	0
Africa	Mtce	6	7	10	15	21	0
Central America and the Caribbean	Mtce	3	3	2	2	2	0
North America	Mtce	5	5	5	4	4	0
Brazil	Mtce	9	7	6	6	6	0
Other South America	Mtce	9	5	2	1	0	0
Total imports		**719**	**617**	**451**	**355**	**229**	**0**

142 For example, we understand from discussions with Colombian officials that the coke industry, which currently sells mostly to the steel industry basic oxygen furnaces, might have options to protect itself by selling a greater share of volumes to industries more resilient to or even benefiting from a global transition, such as metal refining. We treat this potential for companies to mitigate their risks in chapter 4.
143. See IRENA (2021)
144. India's leading producer, Coal India, plans to ramp up production in the short term, allowing India to reduce dependence on imports (https://coal.nic.in/sites/default/files/2022-05/31-05-2022a-wn.pdf). The country has a target to produce 1.2 billion tonnes of coal in 2023/24, up from 716 million tonnes in 2020/21 (https://coal.gov.in/en/major-statistics/production-and-supplies#:~:text=The%20all%20India%20Production%20of%20coal%20during%202021%2D22%20were,a%20negative%20growth%20of%200.98%25.).
145. Source: WTW in-house analysis
146. As well as the pullback of private financing, per IEEFA, the principal public financiers of coal plants all announced an end to international financing in 2021, namely China (https://www.e3g.org/news/no-new-coal-2021-turbocharged-china-end-overseas-finance-cop26/), Japan, and Korea (https://www.wri.org/insights/south-korea-and-japan-will-end-overseas-coal-financing-will-china-catch).
147. Source: WTW and UniAndes analysis, drawing on a range of inputs, including CRU and IEA (2021) and importing country decarbonisation plans

Figure 5: **Delivered coal prices to Rotterdam in BAU and WB2C scenarios**[149]



Lower demand would translate into lower prices in a WB2C scenario at most major pricing nodes, including the API 2 contract delivered to Rotterdam, which forms part of the base price used to calculate the royalties payable by Colombian mines, as illustrated in figure 5[148].

Lower demand and lower prices would likely translate into lower revenues for Colombian coal miners in a WB2C scenario.

The implications of the war in Ukraine for thermal coal prices have had a major impact on coal prices in 2022/23, with the decline in available Russian supply[150] and European attempts to reduce reliance on Russian natural gas pushing prices to more than three times higher than the BAU prices set out in the previous graph[151] .

We ran sensitivities to consider the impact of both a three-year and a ten-year embargo on Russian thermal coal imposed by G7 countries. In the base sensitivities, we assumed that the Black Sea route would be open for Russian volumes shipping south, primarily through the Taman port; in a separate set of sensitivities, we assumed that Black Sea exports were also closed off.

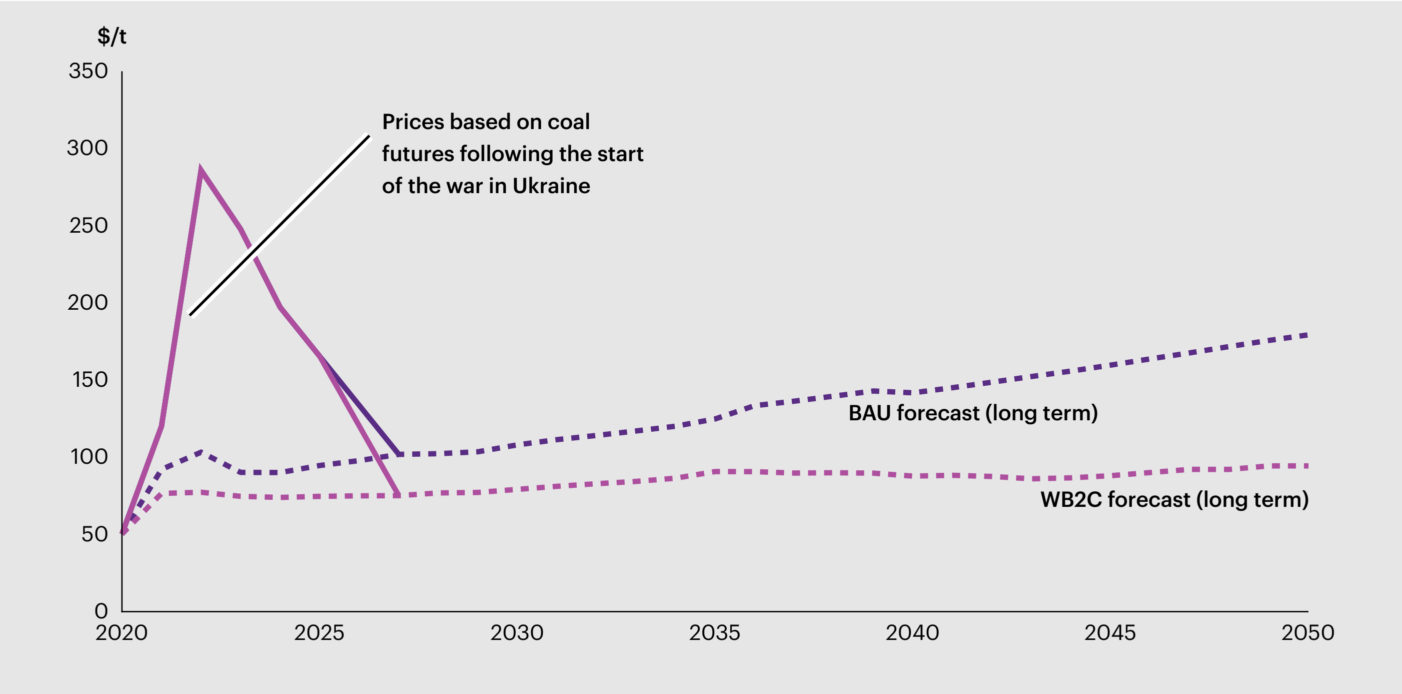
In both cases, exports west, through pre-war primary export ports at Ust-Luga and Riga, are assumed to be constrained[152]. The results of our analysis are set out in figure 7 below.

A prolonged constraint in the availability of Russian supply in the seaborne market would – all things being equal and particularly in a closed Black Sea scenario – push up both BAU and WB2C price curves. However, we expect that a period of prolonged high prices for thermal coal and natural gas would cause demand destruction in the medium term for both of those fuels as countries accelerate the shift to cheaper renewables, particular in countries that are net importers of those fuels. We illustrate how these dynamics may shift the price curves in figure 6.

The impact of the war may – overall – reduce climate transition risk for producing Colombian coal assets and increase the time and resources that the country has to prepare for the phase out of coal exports. It could also complicate the picture for policymakers considering whether to boost investment in new capacity and infrastructure to take advantage of (potentially short term) higher prices.

148. Coal trading takes into account a number of important technical characteristics, including moisture content, the amount of impurities in the coal and in particular, energy content. Our models account for these energy content differentials. The common notation of "MTCE" or "millions of tonnes of coal equivalent" present all volumes with a common calorific value (in this case, 7,004.7 kilocalories per kilogram)
149. Source: UPME
150. Source: WTW in-house analysis. This reflects modelling undertaken before recent commodity price spikes, but we believe still reflects the best long term outlook of how an orderly external transition would affect global coal prices
151. Russian coal embargo: https://www.whitehouse.gov/briefing-room/statements-releases/2022/05/08/fact-sheet-united-states-and-g7-partners-impose-severe-costs-for-putins-war-against-ukraine/
152. Since this analysis was undertaken, spot market prices have risen higher than the prices implied in the graph, which used futures prices at the time of analysis (in April 2022), reaching closer to $400 per tonne. However, the implications of these price changes remain unchanged.

Figure 6: Potential implications of the Ukrainian war on seaborne thermal coal prices[153]

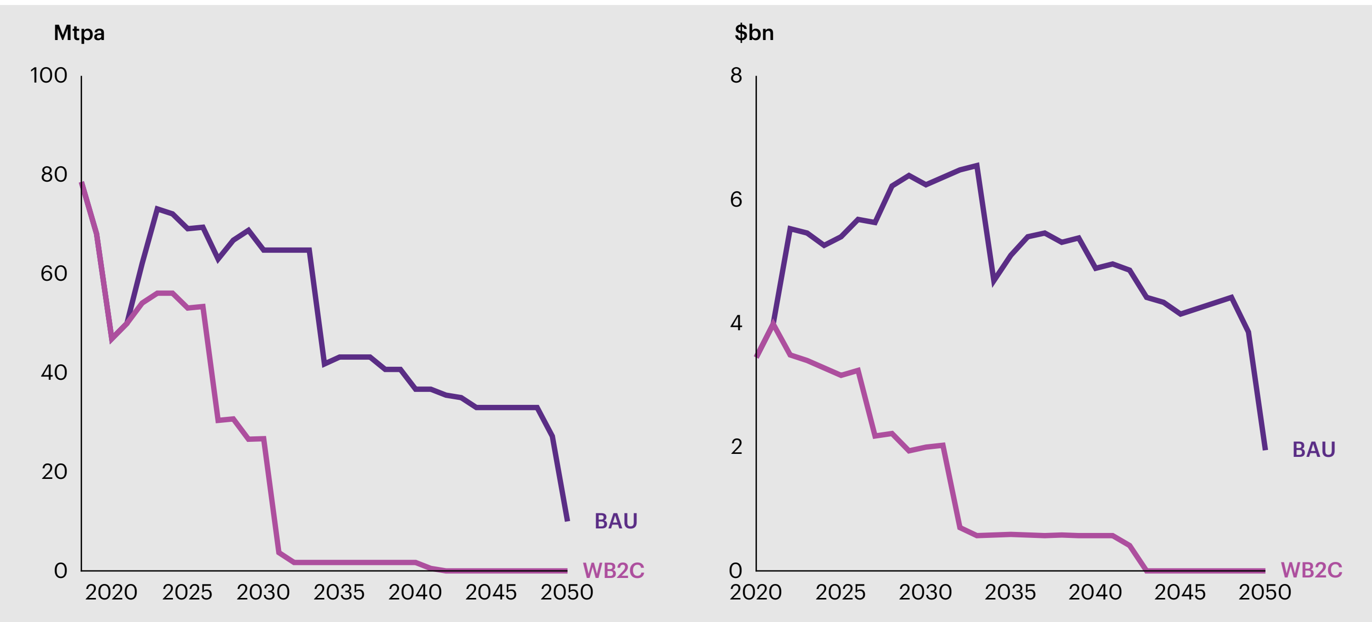


3.2.1.2. Climate transition risk for Colombian coal mining companies

In a period of lower commodity market volatility, prior to the war in Ukraine and the COVID-19 pandemic, Colombia was the fifth largest exporter of thermal coal in the world. In 2019, it exported around 70 million tonnes[154], while consuming a 6-7 million tonnes per year in power plants and industry[155].

Our analysis showed that in a global WB2C scenario, Colombia earns 65% less revenue in net present value terms, driven by a combination of volume and price effects. This equates to **$43 billion** in climate transition downside risk relating to mines primarily operating in export markets.

Figure 7: **Climate transition value at risk for thermal coal[156] Left: Volumes. Right: Revenues.**



153. In June 2022, Interfax estimated that the impact of the G7 ban and restrictions on the availability of insurance for the shipping of Russian coal, exports could be down 30% year-on-year (https://www.reuters.com/article/ukraine-crisis-russia-coal-idUSL1N2Y503E)
154. Source: WTW and UniAndes in-house analysis. NB these prices are API2 prices (delivered to Rotterdam) as per the previous figure
155. DANE exports of nearly 75mt for all coal (https://www.dane.gov.co/index.php/estadisticas-por-tema/comercio-internacional/exportaciones#:~:text=De%20acuerdo%20con%20la%20informaci%C3%B3n,las%20ventas%20externas%20del%20grupo) in 2019. Metallurgical coal and coke exports had historically run at around 3-4mt.
156. See: BECO (https://www1.upme.gov.co/DemandayEficiencia/Paginas/BECOEnergetico.aspx) for historic consumption details

The **$43 billion** figure could be higher if knock-on impacts of coal mining company transition risk mean the early or temporary closure of infrastructure assets such as the Fenoco rail line, Puerto Nuevo (owned by the now defunct Prodeco) and independently owned ports at Santa Marta, Puerto Brisa. Our analysis sets out later in this section suggests that these assets could be face serious challenges.

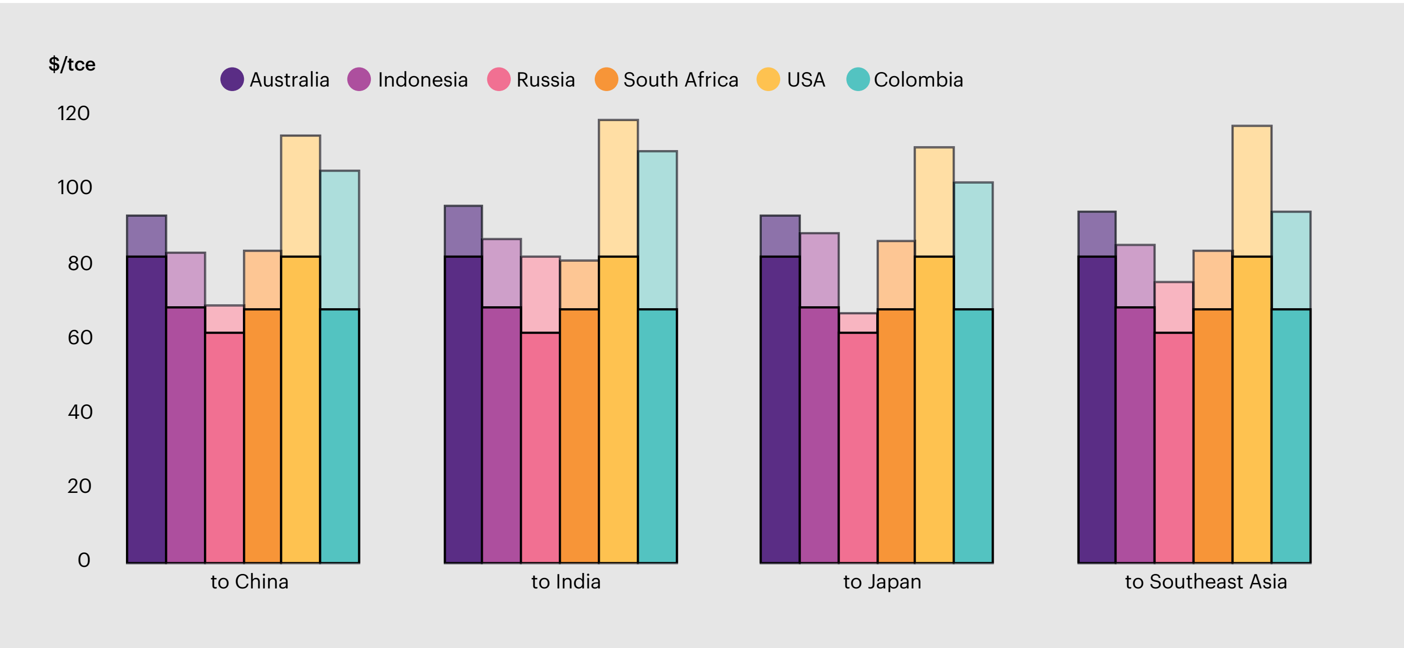
The Colombian coal industry was already in transition before recent events. Financial institutions are accelerating the pullback of capital and insurance from coal companies around the world[157] . Two of the largest global mining companies, BHP Billiton and Anglo American, exited the Colombian coal industry as they sought to deliver on promises to their shareholders to exit the commodity entirely[158] . While Glencore bought out its partners' stakes in the Cerrejón asset, it exited from mines it owned through its Prodeco subsidiary. Several other Colombian mines were mothballed during the COVID-19 crisis[159] .

This notwithstanding, our interviews with government policymakers suggested that there was a strong degree of confidence that, despite the findings of this analysis, Colombian coal would continue to find robust demand in Asia, particularly from markets who may be willing to pay a premium for the relatively high quality and energy content of Colombian coal.

However, our analysis suggests that Colombian coal would struggle to be competitive in the long run compared with other suppliers (such as South Africa, Indonesia, and Russia), given the very high costs of shipping Colombian coal to those destinations. In figure 8 below, we show how despite relatively low mining costs (the solid part of each bar), high shipping costs relative to other competing suppliers (from the left, Australia, Indonesia, Russia, South Africa and the USA) mean that Colombian coal would be more expensive for Asian buyers than coal from any other country other than the USA.

This picture would change in the event of a period with prolonged constraints on Russian supply. In this case, we expect that Colombia's volumes to Japan could increase because Japan is part of a collective G7 embargo on Russian coal. Russian coal might also face competitive pressures in supplying to Turkey and to India, but only if the country were not able to export coal through the Black Sea or the Baltic Sea for a prolonged period. By contrast, Russian volumes are more likely to continue to be available to China and other countries in South-East Asia that have not imposed embargoes, potentially at a discount. This would limit the short-term gains that Colombia could make in terms of volume. Colombia's export infrastructure capacity could also limit the extent to which Colombia's miners could gain from selling additional volumes, in addition to reaping higher profits from higher prices.

Figure 8: **Colombian coal costs for delivery in Asian markets in 2025, compared with competitors[160] (Mining costs are in a darker shade and shipping costs in a lighter shade)**



157. Source: WTW and UniAndes in-house analysis
158. Source: IEEFA
159. Glencore is the only one of the internationally-diversified mining majors left with a significant thermal coal business with BHP BIlliton and Anglo American (https://www.angloamerican.com/media/press-releases/2021/28-06-2021) both seeking to divest from the commodity completely
160. Source: https://www.reuters.com/article/us-glencore-coal-colombia-idUSKBN2G21B7

The longer the disruption persists, the longer Colombian coal volumes will remain competitive, in both BAU and WB2C scenarios, limiting the transition risk impact.

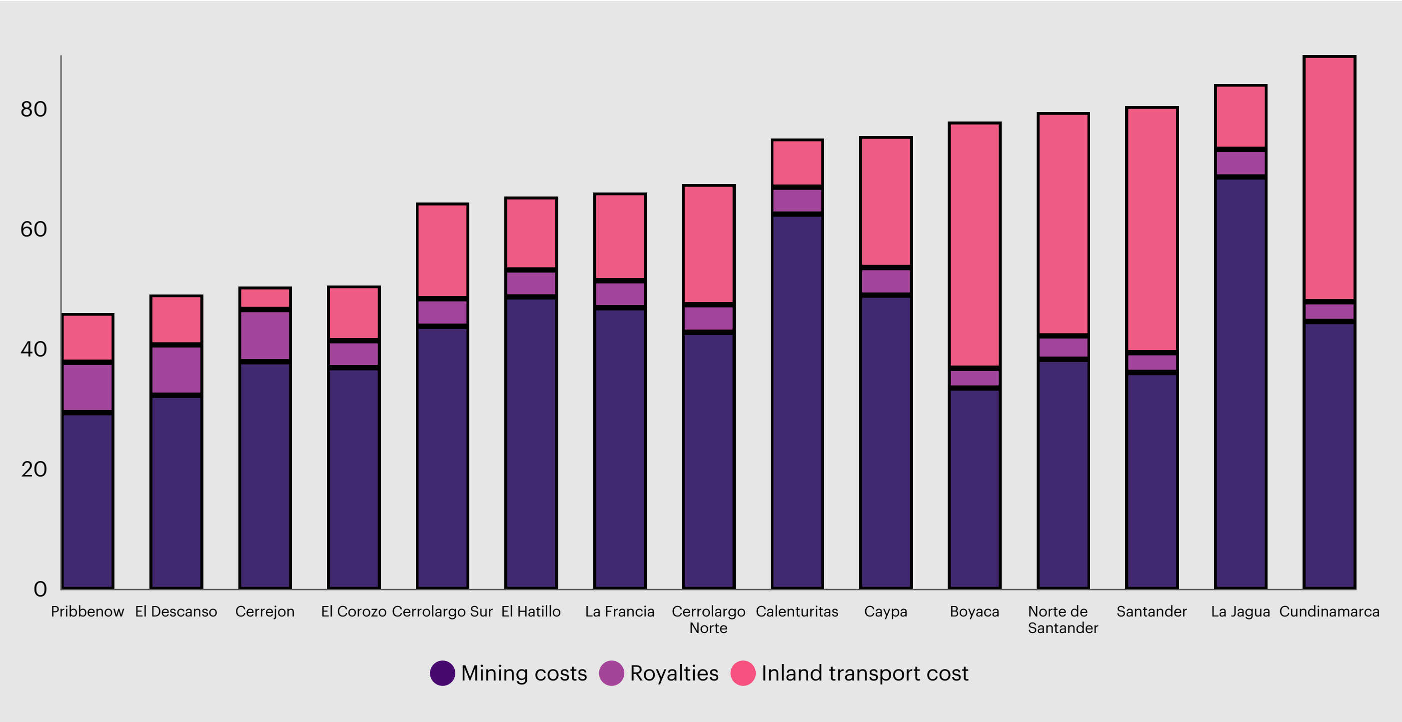
3.2.1.3. Climate transition risk exposure by mine and region

Mining costs (i.e., extraction and processing costs, shown in solid colours in the bars below) for Colombian mines vary less than infrastructure costs (i.e., the cost to transport the coal to ports and load it onto ships) and energy content. Our analysis shows that mines with lower infrastructure costs, particularly Cerrejón, are the most resilient to climate transition risk. Mines in major interior producing regions, such as Boyacá, Cundinamarca, and Norte de Santander, typically produce coal with higher energy content than mines in Cesar and La Guajira, but much higher infrastructure costs (shown in hashed shading in the bars below) impair the competitiveness of coals from those regions.

The relative competitiveness of these mines and regions has a significant influence on their climate transition risk exposure. Whereas mines currently producing in La Guajira export only 16% less coal in a WB2C scenario than in BAU, for mines in Cesar, the figure is 75% less. Several large mines, including El Descanso, could become persistently loss-making before the end of their licenses. Interior mines in our analysis export 93% less coal in a WB2C scenario than in BAU. Our Ukrainian war sensitivities show that Cesar mines may be the biggest beneficiaries in terms of reducing their climate transition risk exposure mentioned in this section.

New mining investments (with the possible exception of extensions to existing sites), are unlikely to be economic in a WB2C scenario, suggesting that investors would suffer losses if the mines are constructed and the WB2C scenario materialises. This also suggests that new infrastructure or infrastructure upgrades related to new coal mines (for example, the expansion of Puerto Brisa), where the economics are dependent on those coal mines, would also be uneconomic.

Figure 9: **Mining costs vs. shipping costs for Colombian mines (WTW and UniAndes estimate, 2022)**



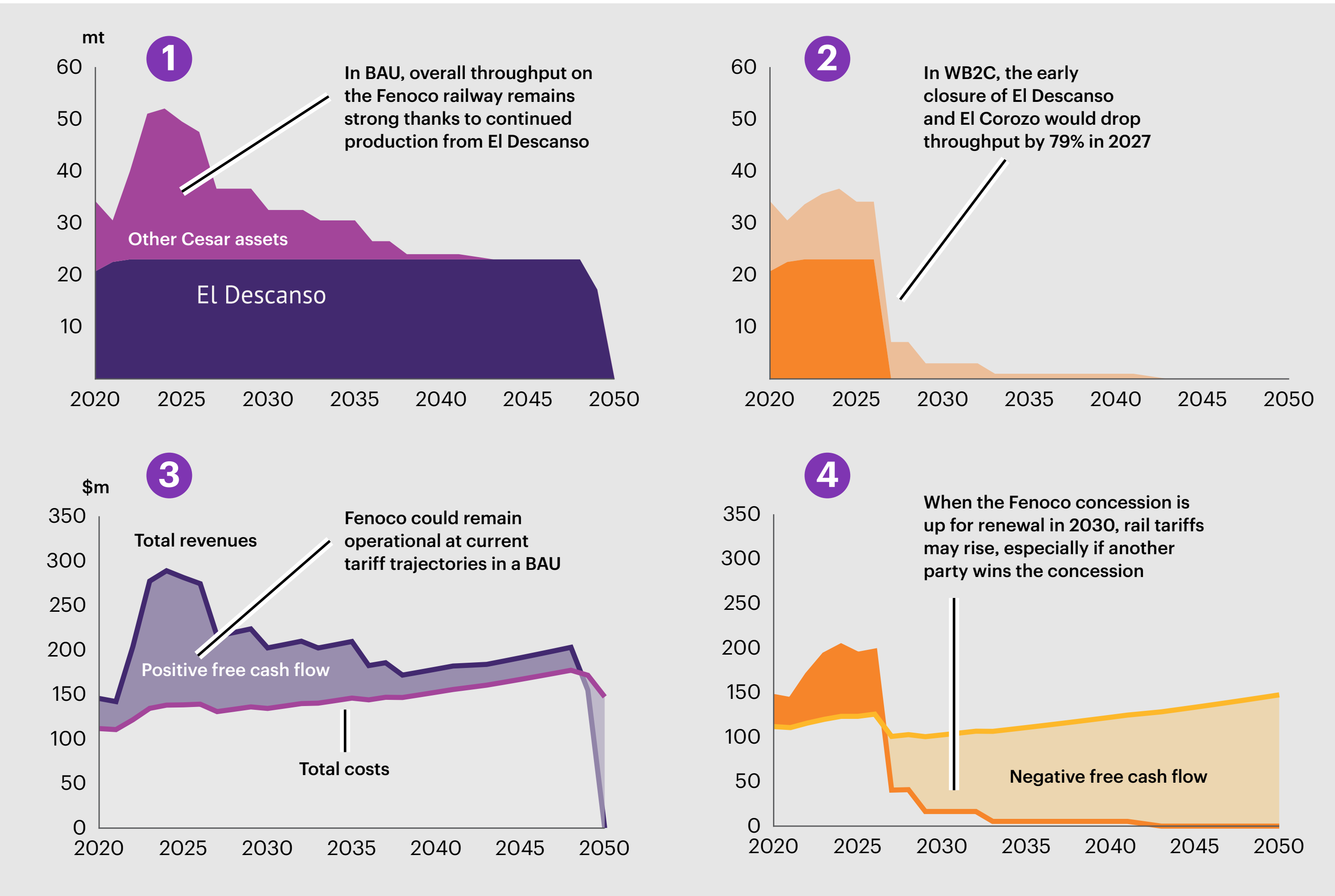
3.2.1.5. Climate transition risk exposure of infrastructure assets

Colombia has several key infrastructure assets, which were either built solely to service the export coal industry or where there is a strong degree of economic reliance on the industry. The economic viability of these assets is therefore largely tied to the continued viability of coal exports. These include much of the rail network leading to the Caribbean coast, including the Fenoco rail concession. Ports including Puerto Drummond, Puerto Bolívar, Puerto Nuevo, Santa Marta, and Puerto Brisa have strong reliance (>50% of handled volumes) on coal today.

This case of Fenoco is particularly relevant as the principal rail line transporting coal from mines in Cesar region to ports. Our analysis showed that if less competitive mines in Cesar were to close early, this would reduce volumes transported on Fenoco, turning it persistently loss-making. Fenoco too, would therefore benefit from an improvement in the fortunes of Cesar mines arising from a prolonged disruption to global coal markets.

Colombia's strategy to expand the use of rail as a means of transporting freight may mean that options are available for diversifying the cargo carried on the line. We understand, the current plan is to bring Fenoco into line with the rest of the rail infrastructure[162] only by the 2030s after the end of the company's current concession. However, our analysis shows that the downside risks associated with a global transition for Fenoco and key ports could materialise in the 2020s (as shown in Figure 10), suggesting that accelerated transition planning for these assets should start soon. It is important to note that these risks are concentrated on specific parts of Colombia's national rail infrastructure (that service coal exports) and will not be as relevant for wider plans around developing rail transport in Colombia, for public and non-coal freight uses.

Figure 10: **Potential impact of a decline in coal volumes on the Fenoco railway**[161]



161. Analysis based on WTW in-house global thermal coal model
162. Source: WTW and UniAndes in-house analysis

3.2.2 Crude oil and oil products

3.2.2.1. Global transition dynamics for oil markets

Globally, oil products are used in a very wide variety of applications, but they are most widely used as transport fuel. Different segments of oil demand will be impacted by a global low carbon transition at different times as the cost of low carbon alternatives fall. We expect that this will happen earlier in light duty vehicles than in heavy duty freight vehicles or aviation. Outside of transport fuels, the use of oil in the production of plastics has been rising sharply in recent years and remains a particularly complex sector to decarbonise.

The fact that a meaningful amount of oil demand today is in "hard-to-abate" sectors means that a sharp drop off in demand is unlikely in this decade. However, oil demand does peak in the 2020s in our WB2C scenario, approximately 10 years earlier than in the BAU scenario, as illustrated in table 16.

To a much greater extent than the other sectors covered in this chapter, small differences in demand can lead to significant changes in crude oil prices, due to particularly steep shape of the global crude oil supply curve. As illustrated in figure 11, global oil prices rise gradually in a WB2C scenario but much more sharply in a BAU scenario, where higher demand leads to a much higher amount of investment in new supply to be spent to meet demand.

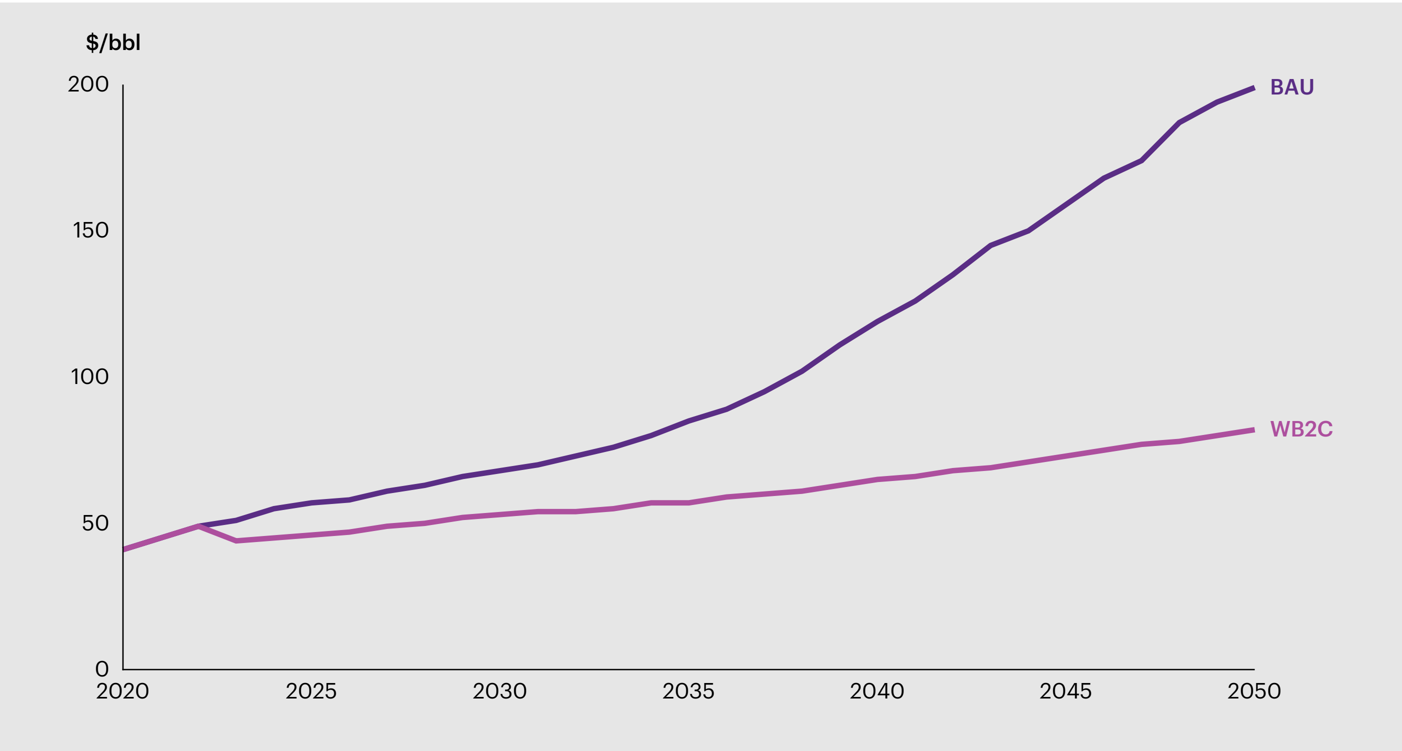
We also expect a WB2C scenario to result in lower global refining margins as demand decline could create oversupply of refining capacity, particularly for heavier products. Lower oil prices and lower refining margins would put downward pressure on profits for Colombian oil producers and refiners in a WB2C scenario, relative to a BAU scenario.

As with thermal coal, the war in Ukraine has created significant disruption in both oil and oil product markets.

Table 16: **Crude oil demand scenarios (global)**[163]

		2019	2025	2030	2035	2040	2050
BAU	Mbbl/d	100	97	101	101	101	100
WB2C	Mbbl/d	100	90	84	74	64	45

Figure 11: **Brent oil price scenarios[164] – (prior to war in Ukraine)**



163. Source: Plan Maestro Ferroviario - https://colaboracion.dnp.gov.co/CDT/Prensa/Plan-Maestro-Ferroviario.pdf
164. Source: WTW in-house analysis

The US imposed an oil embargo on Russian oil, while the EU's ban on importing Russian oil products was implemented from February 2023. However, despite the price cap imposed by the G7 in late 2022, the supply side of the crude market has been disrupted to a lesser degree than in the thermal coal markets. On the eve of war in late February 2022, Brent prices had already nearly doubled since the start of the year, before peaking in June 2022 and beginning a gradual decline. Prolonged periods of high oil prices may generally be less likely than a prolonged period of thermal coal prices, given a greater amount of quick-to-deploy "spare" crude production capacity in swing suppliers like the US shale industry. However, if a prolonged period of high prices were to result, this would push up both BAU and WB2C curves, having a limited impact on transition. Even a short period of higher oil prices could supercharge an already accelerating consumer switch to from gasoline and diesel to electric vehicles.

3.2.2.2. Climate transition risk for Colombian oil sector companies

In 2019, Colombia earned around $16 billion from the export of crude oil and oil products or 39% of the country's total exports, while it also paid around $2 billion (or around 8% of total imports) to import gasoline and crude. The oil value chain is currently the most important contributor to Colombia's trade balance, with a persistent oil surplus going a long way to protect Colombia's external balance which, in total, has been negative every year since 2012[166] (even in 2021, a year of coal and oil super-profits).

The oil sector is also currently one of the most important for Colombia's economy, with Ecopetrol dividends being an important source of government revenue, while the company is the largest on the Colombian stock exchange in Bogotá. The country also produces the bulk of the liquid fuels it consumes, through two main refineries, located at Cartagena and at Barrancabermeja, in Santander.

Like the thermal coal export business, Colombia's crude oil exports face climate transition risk downside relating to the impact of the global transition on global prices. However, unlike the thermal coal export business, the level of climate transition risk faced by crude oil exports is moderated by the fact that crude exports are expected to decline even in a BAU scenario because of the natural decline of commercially recoverable onshore reserves[167].

Total climate transition value at risk of **$33 billion** relating to crude oil production represents – at 27% of BAU value – a much smaller exposure than the 65% downside faced in the thermal coal export business.

Compared with the coal business, the Colombian oil value chain is much more tightly integrated into global markets. In a WB2C scenario, a combination of lower international prices for oil products, combined with a rising need for imported heavy crude means Colombia's refineries could face a further **$6.9 billion** of downside risk, while Barrancabermeja could potentially become persistently lossmaking before the end of its economic life.

Table 17: **Colombian oil and oil products trade balance, global BAU vs. WB2C scenarios[168]**

		2019	2025	2030	2035	2040	2050
BAU crude net exports	$ bn	12.7	4.4	0.5	-3.7	-8.8	-22.2
BAU product net exports	$ bn	-0.7	0.4	0.3	0.2	1.0	3.5
WB2C crude net exports	$ bn	12.7	3.0	-0.4	-3.0	-5.2	-9.9
WB2C product net exports	$ bn	-0.7	0.3	0.2	0.0	0.4	1.4
BAU balance	**$ bn**	**12.0**	**4.8**	**0.8**	**-3.5**	**-7.8**	**-18.7**
WB2C balance	**$ bn**	**12.0**	**3.3**	**-0.2**	**-3.0**	**-4.8**	**-8.5**

165. Source: WTW in-house analysis
166. Source: DANE
167. Source: Rystad Energy and WTW in-house oil analysis
168. Source: WTW and UniAndes in-house analysis

Lower fuel prices could also translate into a cumulative gain[169] for oil consumers of **$39 billion**, although those consumers would also be affected by the negative impact on the trade balance[170].

Colombia's climate transition risk exposure in crude oil production results from the impact of lower global demand for oil in a WB2C scenario, resulting in lower global prices. As shown in figure 12, our analysis suggest that Colombia would see only a small amount of volume stranding, producing 8% less between 2021 and 2050 than in a BAU scenario.

In the short run, Colombian producers stand to reap outsize profits from the current period of very high global crude prices. We estimate that revenues could top $25 billion in 2022, compared with $10.5 billion in 2020. In our view, the greater availability of flexible, quick-to-mobilise supply makes a prolonged period of elevated prices less likely in crude oil than in natural gas or thermal coal.

We do not expect the impact of the war to have a material impact on Colombia's climate transition risk exposure unless a period of higher prices encourages investment in fields that would otherwise have been marginal. However, we do expect increasing and intensifying geopolitical tensions to increase crude oil price volatility as the global climate transition plays out.

3.2.2.3. Climate transition risk exposure by field and region

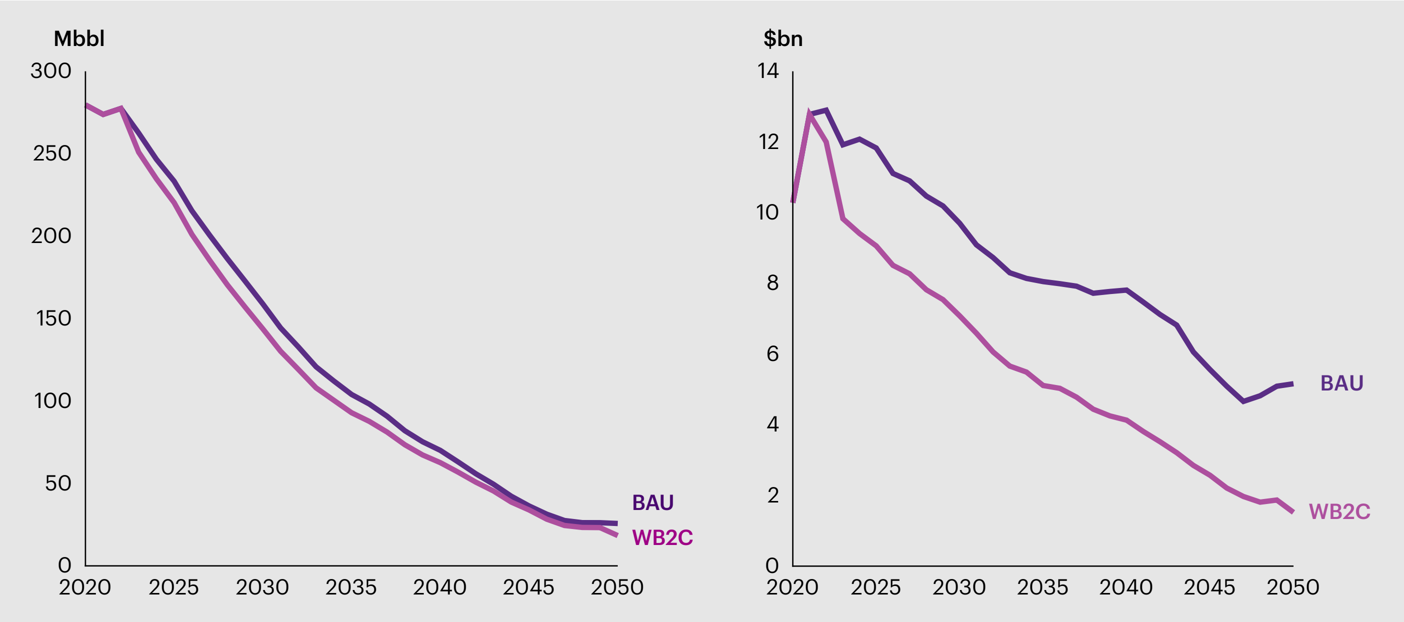
In the upstream business, our analysis shows the Llanos basin remaining by far the largest crude oil producing region over 2021-2050, with the majority produced in the Meta department. Our analysis showed that production in Meta faces greater downside risk in a WB2C transition, compared to other departments, since the producing Quifa field becomes uneconomic, and several potential new fields become marginal.

The Reficar and Barrancabermeja refineries could face more significant downside risk (the latter facing risk equating to 55% of BAU value), driven by lower global refining margins and rising cost of importing the appropriate qualities and quantities of crude feedstock as Colombian domestic production declines.

Our analysis shows that Barrancabermeja faces greater climate transition risk than Reficar. In part, this is because of its technical configuration. Barrancabermeja (Barranca) produces a range of products (the refinery's "slate") that includes a higher share of heavier, lower value products (like asphalt, tar), than Reficar[172]. We expect demand for many heavy refined products to drop off faster in a low carbon transition than lighter products, meaning greater downside risk for those products.

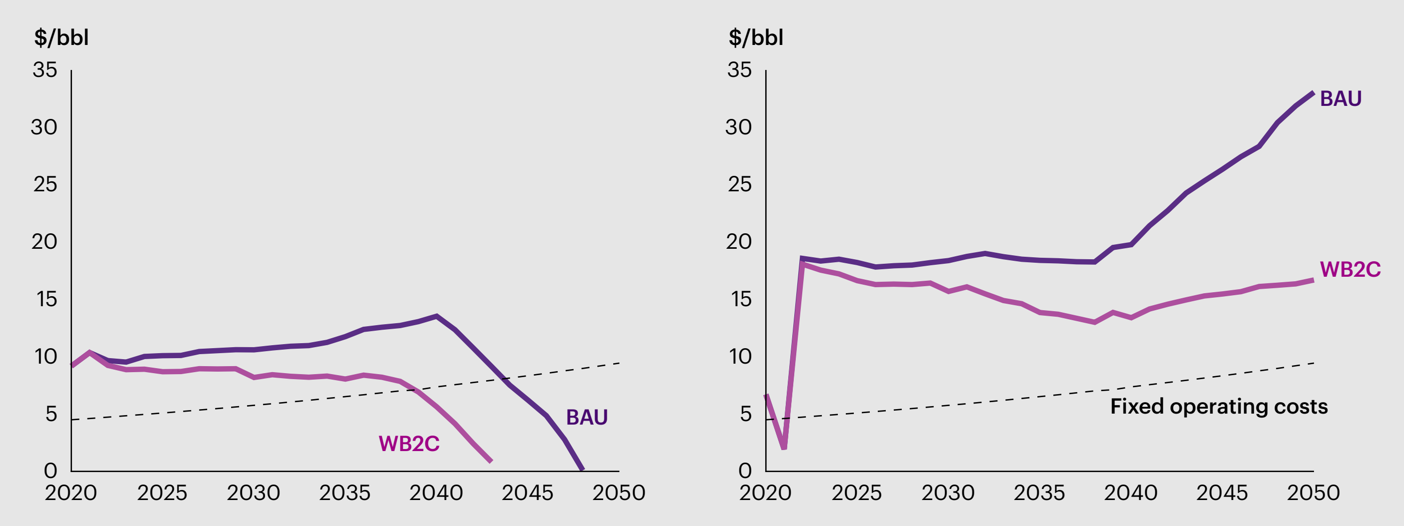
This means that while Reficar's margins are also lower in a WB2C scenario than a BAU scenario, Barrancabermeja has a lower margin of safety. Figure 13 illustrates this: Reficar's margins are not only higher in absolute terms, but the impact of the global transition is also less severe.

Figure 12: **Volume vs. value at risk for Colombian conventional crude oil production**[171]



169. This would likely be shared between consumers and government, through the FEPC stabilisation fund
170. As discussed further in chapter 4, the impact of a persistent decline in Colombia's trade balance would most likely be felt through a depreciation of the peso, which, in turn would lead to imported inflation more generally. This could partially offset some of the benefit of lower dollar fuel prices
171. Source: WTW and UniAndes in-house analysis
172. In 2021, Barrancabermeja produced 214,616 barrels per day of fuel, of which 58,342 (or 27%) were heavier, lower value fuel oil and asphalt. By contrast, Reficar produced 136,586 barrels per day of fuel, of which 4,439 were heavier products only made up 3%. Source: https://www.sec.gov/Archives/edgar/data/1444406/000141057822001007/ec-20211231x20f.htm#a3711BarrancabermejaRefinery_182554

Figure 13: **Refining margins across both BAU and WB2C scenarios[173] Left: Barrancabermeja. Right: Reficar.**



In this context, declining production of Colombian heavy crude from the Llanos basin, previously a captive source of feedstock for Barrancabermeja, could present a severe challenge for the inland refinery. As domestic production falls, we expect that Barrancabermeja would need to import increasing volumes of heavy crude, with additional cost eating into already thin margins. In its current configuration, Barrancabermeja could become loss making in the late 2030s unless investment is undertaken to reconfigure it to produce a higher share of higher value lighter products, chemical and perhaps lower carbon fuels, such as biofuels.

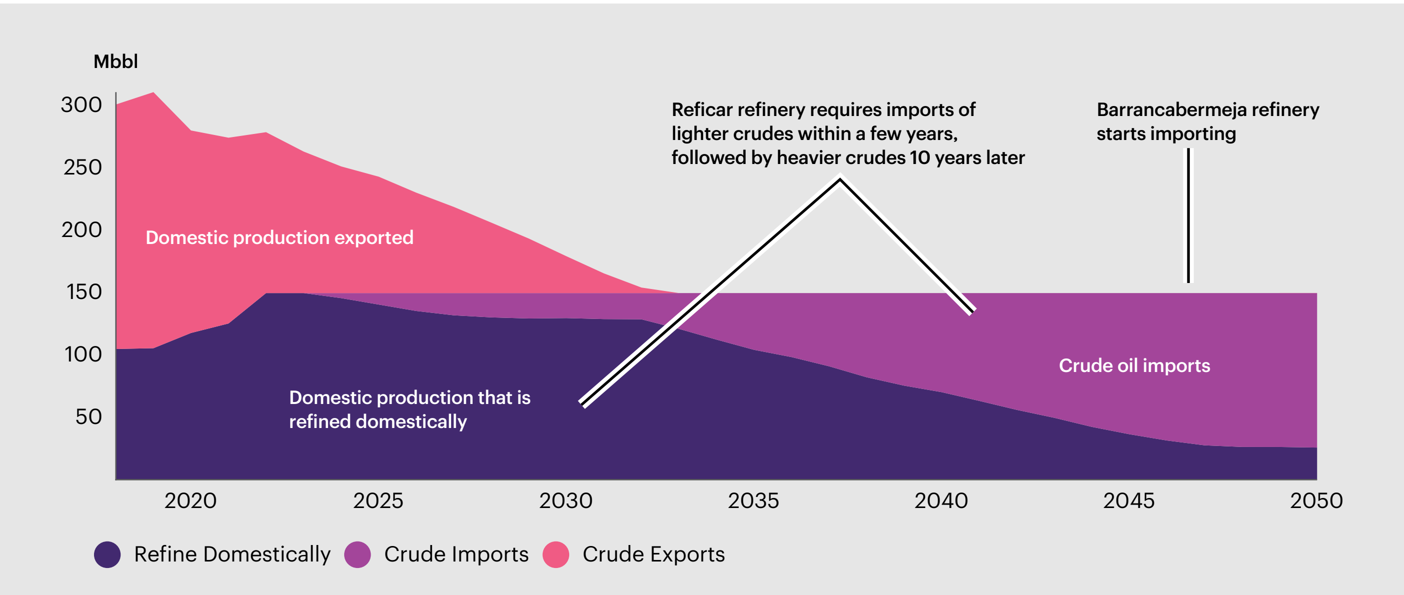
3.2.2.4. Climate transition risk exposure of infrastructure assets

Declining domestic production, as noted above, could put pressure on Colombian crude oil exports, which, in our analysis, could cease by the mid-2030s as domestic production is preserved to cover domestic demand, as illustrated in figure 14.

A decline and eventual end of crude oil exports would not necessarily mean an end to volumes being transported through the Coveñas port and in the pipeline between Coveñas and Barrancabermeja, but investment might be required to ensure that liquids could flow inland, as Colombia becomes a net importer of crude. This would likely need to happen in both a BAU and a WB2C scenario.

Oil and gas infrastructure, including ports, pipelines, storage facilities and regasification terminals, face greater climate transition risk from a potential accelerated domestic transition (as described in chapter 5), as their economics are to a large degree dependent on volume (as opposed to price) and hence, on domestic demand for oil products and gas.

Figure 14: **Crude oil flows in a BAU scenario[174]**



173. Source: WTW and UniAndes analysis
174. In this graphic, Colombia starts to import crude despite also exporting, given the need to source appropriate volumes of the right qualities of oil to satisfy refinery "crude diets"

3.2.3 Natural gas

3.2.3.1. Global climate transition dynamics for natural gas markets

Of all the commodities covered in this chapter, the long-term prospects for natural gas demand have shifted the most in recent years. Once widely seen to be a "transition fuel" in the power sector globally, growth in global gas demand has moderated over the last decade as prices for importing countries have risen, making gas increasingly uncompetitive in power generation compared with internationally-traded coal and wind and solar power, whose costs have fallen dramatically[175]. This trend has been exacerbated by sharply increased liquefied natural gas prices (LNG) since the outbreak of war in Ukraine.

The fuel's environmental credentials vs. coal are also increasingly questioned with the publication of increasing evidence about the extent of fugitive emissions from gas wells and methane links in natural gas infrastructure[176]. Away from power generation, gas demand has grown within many emerging markets as a cleaner (in the sense of air pollution) alternative to oil in transport and biomass in residential heating and cooking[177]. The use of natural gas also continues to grow in the chemical industry, particularly as a feedstock for the production of ammonia, a key component of nitrogen fertilisers.

The structure of natural gas markets has also been changing. First, over the last decade the share of natural gas transported as LNG has grown as the market has globalised. Second, a range of new sources of supply have entered the market, not least the US, which first exported LNG in 2016 but in 2022 became the largest source of supply[178]. These dynamics had a significant impact on competitive dynamics and generally kept import prices low and stable until the record price spikes starting in 2021.

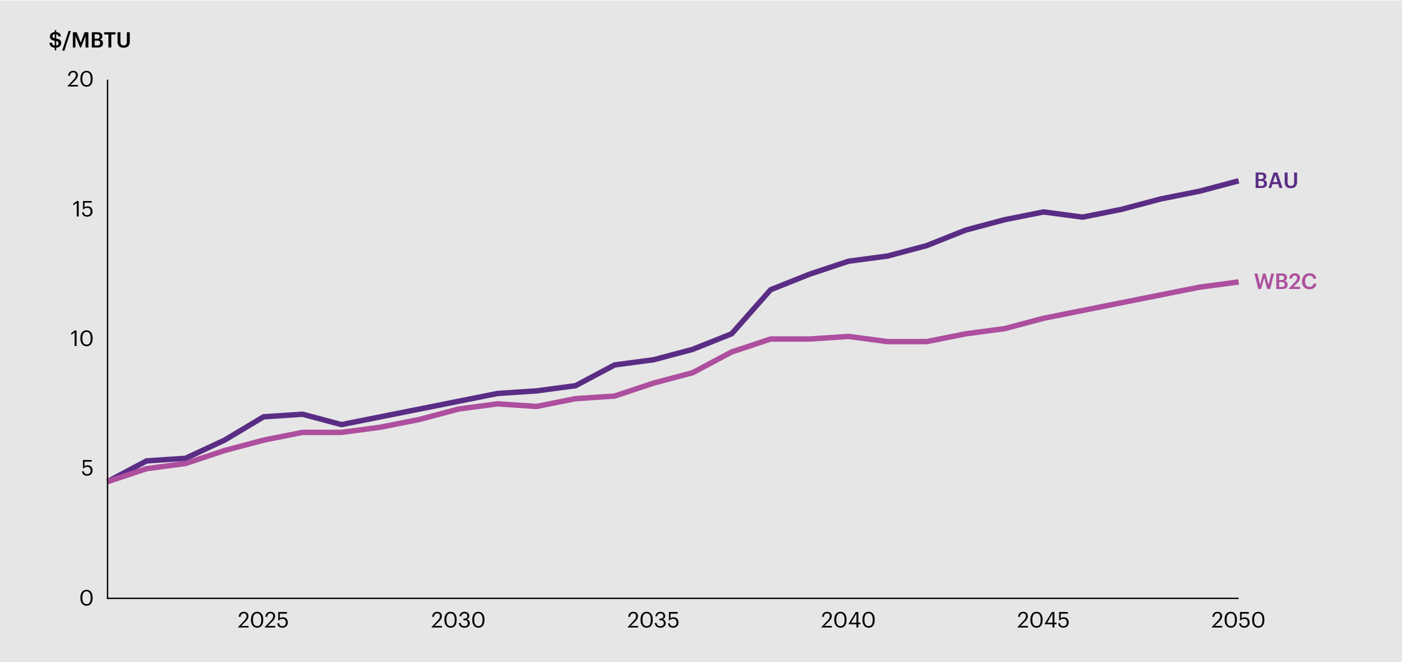
The scenarios used in this project used are focused on the LNG market, which currently is the marginal source of demand in Colombia, imported into Cartagena. However, as illustrated in table 18, we expect globally traded LNG volumes to grow in both BAU and WB2C scenarios, even while total gas demand falls in a WB2C scenario. This is the result of an increase in the share of global gas demand coming from Asia, mostly supplied by LNG, and a phase-out of gas in Europe, which has historically had a much larger share of gas supplied by pipeline.

Table 18: **Natural gas and LNG demand scenarios (global)**

		2019	2025	2030	2035	2040	2050
BAU Natural gas	Bcm	4,020	4,357	4,613	4,916	5,221	5,909
BAU LNG	Bcm	488	543	641	740	838	1,096
WB2C Natural gas	Bcm	4,020	4,166	3,997	3,776	3,554	3,161
WB2C LNG	Bcm	488	522	592	613	631	673

175. https://about.bnef.com/blog/scale-up-of-solar-and-wind-puts-existing-coal-gas-at-risk/
176. https://a9w7k6q9.stackpathcdn.com/wpcms/wp-content/uploads/2020/11/Methane-Emissions-from-Natural-Gas-and-LNG-Imports-an-increasingly-urgent-issue-for-the-future-of-gas-in-Europe-NG-165.pdf
177. Source: https://www.mckinsey.com/~/media/mckinsey/industries/oil%20and%20gas/our%20insights/global%20gas%20outlook%20to%202050/global-gas-outlook-2050-executive-summary.pdf
178. Source: https://www.eia.gov/todayinenergy/detail.php?id=53159#:~:text=The%20United%20States%20became%20the%20world's%20largest%20liquefied%20natural%20gas,day%20(Bcf%2Fd).

Figure 15: **Delivered LNG prices to Colombia**[179]



The expected growth in LNG demand implies that, for markets where LNG is usually the marginal and hence price-setting gas source, gas prices are likely to rise over time in order to cover the cost of building new LNG infrastructure, as illustrated in figure 15.

Rising gas prices may further limit the value of the commodity as a "transition fuel". This trend has not only been relevant in power generation, but also in a range of industrial sectors (such as hydrogen production and steel production), given that the cost of low-carbon alternatives is projected to continue to fall, spurred by falling renewable energy prices and economies of scale in the manufacturing of key low-emissions technologies, such as electrolysers[180]. Colombia's ability to avoid this impact, will depend on the extent to which a swift ramp-up of offshore gas production is possible, something which is uncertain given the early phase of the Uchuva-1 discovery and the technical challenges around the Gorgon-2 discovery[181] .

The fading of the credibility of the "gas as transition fuel" paradigm could accelerate in the event of prolonged high prices arising from the war in Ukraine and sanctions on Russia. LNG prices have been impacted to a much greater degree than crude oil or thermal coal, principally because the much greater importance of Russia as the largest global producer of natural gas. Global LNG prices are currently materially higher than the 2022 price in our BAU scenario shown above. A prolonged period of high prices would likely lift both the BAU and WB2C curves in the short run, before leading to demand destruction in the medium term.

3.2.3.2. Climate transition risk for Colombian natural gas users and producers

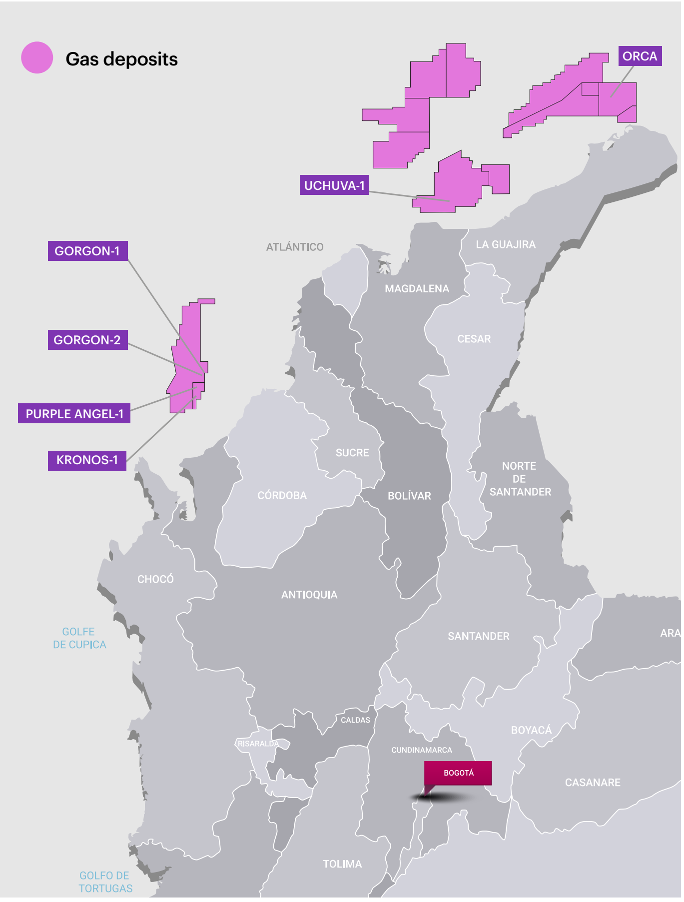
Colombia uses natural gas in a wide variety of ways - to generate power, as a transport fuel, for use as a cooking and heat source in residential and industrial settings and as an industrial feedstock. From the time that Colombia started using gas until 2016, Colombian gas production made the country self-sufficient, meaning that the market was largely insulated from developments in international markets. With domestic production starting to decline and the entry of US volumes into an already oversupplied global LNG market causing prices to remain low, Colombia took the decision to build a regasification terminal at Cartagena to enable the import of LNG. However, with domestic demand continuing to rise[182] , conventional domestic production continuing to fall and Cartagena projected to approach its maximum import capacity in the current decade, Colombia is now facing two important strategic decisions: a) whether to expand LNG import capacity, either at Cartagena and/or a new regasification facility at Buenaventura in the Pacific; and/or b) whether to rely on future increases in production from newly discovered offshore resources as a means to avoid expanding import capacity. The decisions as to which combination of these developments (or whether to pursue any of them at all), will have an important impact on the country's climate transition risk exposure.

179. Source: WTW and UniAndes analysis
180. Source: https://www.irena.org/publications/2020/Dec/Green-hydrogen-cost-reduction
181. The Uchuva-1 discovery is at an earlier stage than Gorgon-2 as the discovery was announced after just one exploratory well (https://www.offshore-energy.biz/new-deepwater-gas-discovery-offshore-colombia/). Gorgon-2 is a step further ahead, but is in deeper water at 4,000m depth, compared with 830m for Uchuva (https://www.offshore-energy.biz/fresh-deepwater-gas-discovery-for-shell-offshore-colombia/). It is also further from shore. These two issues will add to the complexity of bringing it to production
182. For as long as Colombian climate policy envisages natural gas as a climate solution, demand for it is likely to rise

Table 19: **Colombian gas demand, production, and imports (global BAU and WB2C, no shale, pre-offshore)**[183]

BAU		2019	2025	2030	2035	2040	2050
Demand	Bcm	10.9	11.5	11.8	12.0	12.4	12.9
Colombian production	Bcm	11.1	7.7	4.1	2.1	1.5	1.3
Imports	Bcm	0.4	3.8	7.7	9.9	10.8	11.6

Figure 16: **Map of potential new offshore gas deposits**[184]



Our global BAU scenario assumes the development of the Buenaventura terminal only and that Colombian shale gas development do not go ahead. In this scenario, Colombian imports continue to rise, aided by the additional of new regasification capacity, with the same scenario obtaining in a global WB2C scenario where the domestic baseline remains the same.

The announcement, in August 2022, of significant progress in exploration offshore in the north of Colombia could change this picture somewhat.

Of the two most advanced assets, Gorgon-2 is a complex find in very deep waters with large reserves that could be 6 trillion cubic feet or more[185]. At Gorgon-2, the well drilled in 2022 served to confirm the presence of gas that was first announced as a discovery in 2017. By contrast, Uchuva-1 is in shallower waters, and closer to shore, but is at an earlier stage of exploration, with no resource estimate yet published.

The potential impact of these assets (and any follow-on assets which may be viable if these assets are developed) on Colombia's natural gas balance will depend to a large degree on a) the time to develop the assets to the point of production; b) extraction costs and c) additional infrastructure costs to bring the gas to the coast. If Colombia is able to bring sufficient new gas online and early enough to cover domestic demand and obviate the need for additional investments in LNG capacity, Colombia's gas prices may become delinked from international prices over the longer term, protecting Colombia's gas users and producers from external climate transition risk.

However, the complexity of deepwater assets has meant that only 3 assets discovered since 2000 have taken less than seven years to the start of production[186]. This would imply that Colombia would be unlikely to bring on significant offshore production before 2030. If Gorgon-2 was developed along that timeframe and delivered at its maximum potential capacity, our analysis shows that it could make Colombia self-sufficient in gas for three years in the early 2030s.

183. Source: WTW and UniAndes analysis
184. Map taken from Ecopetrol website
185. Given the early stage of development of these deposits, estimating recoverable resources is challenging. Prior to the August announcements, the ANH had estimated a potential 6 TCF, with a further potential 1 TCF in the Kronos 1B field, which is very close (source: https://www.anh.gov.co/documents/14854/Exploration_Trends_in_Colombia_by_Carlos_Maceralli.pdf). A 2020 estimate from Ecopetrol quoted (3 TCF) (source: https://www.ecopetrol.com.co/wps/wcm/connect/3718f40f-54ab-453c-bc23-e62377eb4ece/Comunicado+Shell+-+ENG.pdf?MOD=AJPERES&attachment=false&id=1608755917315). Given that recoverable reserves are unlikely to amount to 100% of estimated maximum potential at this time, we took an assumption of 5 TCF for our sensitivity, based on 70% of the ANH estimates. If the outturn is lower, Colombia would become more depending on gas importers whereas if the outturn is higher, Colombia would have a greater chance of self-sufficiency in gas.
186. The three assets in question are Sakarya 1 (Turkey), Tamar 1 (Israel) and Zohr (Egypt). However, these are the exceptions. Others with much longer development periods include: Liwan and Lingshui (China), Akpo (Nigeria), Gorgon 2 (Australia), Leviathan (Israel) and Mozambique developments other than Coral FLNG

Table 20: **Colombian gas demand, production, and imports (global BAU and WB2C, no shale, including Gorgon-2 ramping up in 2030)**[187]

BAU		2019	2025	2030	2035	2040	2050
Demand	Bcm	10.9	11.5	11.8	12.0	12.4	12.9
Colombian onshore	Bcm	11.1	7.7	4.1	2.1	1.5	1.3
Colombian offshore	Bcm	-	-	1.0	9.6	9.2	2.1
Imports	Bcm	0.4	3.8	6.7	0.3	1.7	9.5

Table 21: **Increasing linkage of average Colombian wholesale natural gas prices to spot LNG prices**[188]

		2019	2021	2023	2024	2025	2026
International price linkage	%	0	1	24	25	33	45

Table 22: **Colombian natural gas import bill, global BAU vs. WB2C scenarios (without offshore gas)**[189]

		2019	2025	2030	2035	2040	2050
BAU	$ bn	0.1	0.9	2.1	3.2	5.0	6.6
WB2C	$ bn	0.1	0.8	2.0	2.9	3.9	5.2

At this stage, we can conclude the following: 1) that Colombia is likely to become more reliant on LNG imports in the 2020s; 2) that there is a chance of Colombia becoming self-sufficient in natural gas for the early part of the 2030s but subject to uncertainty around timing, volume and cost; and 3) there would be a much greater chance of Colombia becoming self-sufficient in natural gas in the long term if it were to implement domestic policies that reduce the use of (or reduce the growth in the use of) natural gas in the Colombian economy. However, given the uncertainty about the costs and timing of bringing Gorgon-2 (let alone Uchuva-1) to production, and Colombian domestic transition policy that includes the use of natural gas in the long term (see chapter 5) it would be prudent to assume that Colombia's gas prices will trend closer to international prices both in the 2020s and in the short term (see analysis in the table below).

Given these dynamics, Colombia would see a rising import bill for natural gas over time in both global scenarios and even in the event of a timely entry from offshore gas (as illustrated in table 22).

We calculated the value of this **gain** in a global WB2C scenario relative to BAU from lower import costs, with an NPV impact of **$4 billion**.

For gas **producers**, their climate transition risk exposure will rise in natural gas will increase as Colombian gas prices become more closely linked to international prices.

Historically, wholesale prices for natural gas produced in Colombia were mostly struck in bilateral contracts between producers and buyers with relatively long tenors of up to seven years[190]. When the Cartagena LNG terminal opened, this opened the possibility for northern Colombian power plants close to Cartagena to access what was then lower-cost LNG[191]. They secured this option by signing a ten-year contract that gave them the right but not the obligation to offtake LNG imports into Cartagena[192]. However, we are not aware of any price stabilisation agreements, meaning that Colombian LNG importers have remained subject to international prices. While the level and volatility of international prices remained relatively low, northern Colombian power plant owners benefited. However, amidst the recent

187. Source: WTW and UniAndes analysis
188. WTW and UniAndes analysis
189. Source: WTW and UniAndes analysis
190. Canacol has benefited from regularity of cash flows secured by long term contracts. Source: https://www.fitchratings.com/research/corporate-finance/fitch-upgrades-canacol-energy-ltd-to-bb-outlook-stable-13-05-2022
191. Source: https://www.fitchratings.com/research/corporate-finance/colombian-gas-utilities-are-insulated-from-high-international-prices-02-05-2022
192. Source: https://links.sgx.com/FileOpen/TPL%20Final%20OM%20(Reopening)_Reduced2.ashx?App=Prospectus&FileID=41984

sharp rise in international prices, Colombian power plant owners have reduced their LNG imports, reverting to lower-priced domestic gas[193]. The Colombian natural gas market remains bifurcated, with domestic gas not being priced at import parity, but this could be about to change.

The structure of the Colombian gas market has largely protected Colombian consumers against recent price spikes related to the war in Ukraine and may have given Colombian gas consumers the impression that natural gas is generally cheap. However, with declining onshore gas production, a likely slow ramp-up of offshore production and the planned expansion of Colombia's gas pipeline network (which would LNG to be sold across Colombia and to compete with domestic producers), these dynamics are unlikely to persist beyond the next few years. In this scenario, we expect average Colombian wholesale gas prices to rise over time and to trend towards international prices.

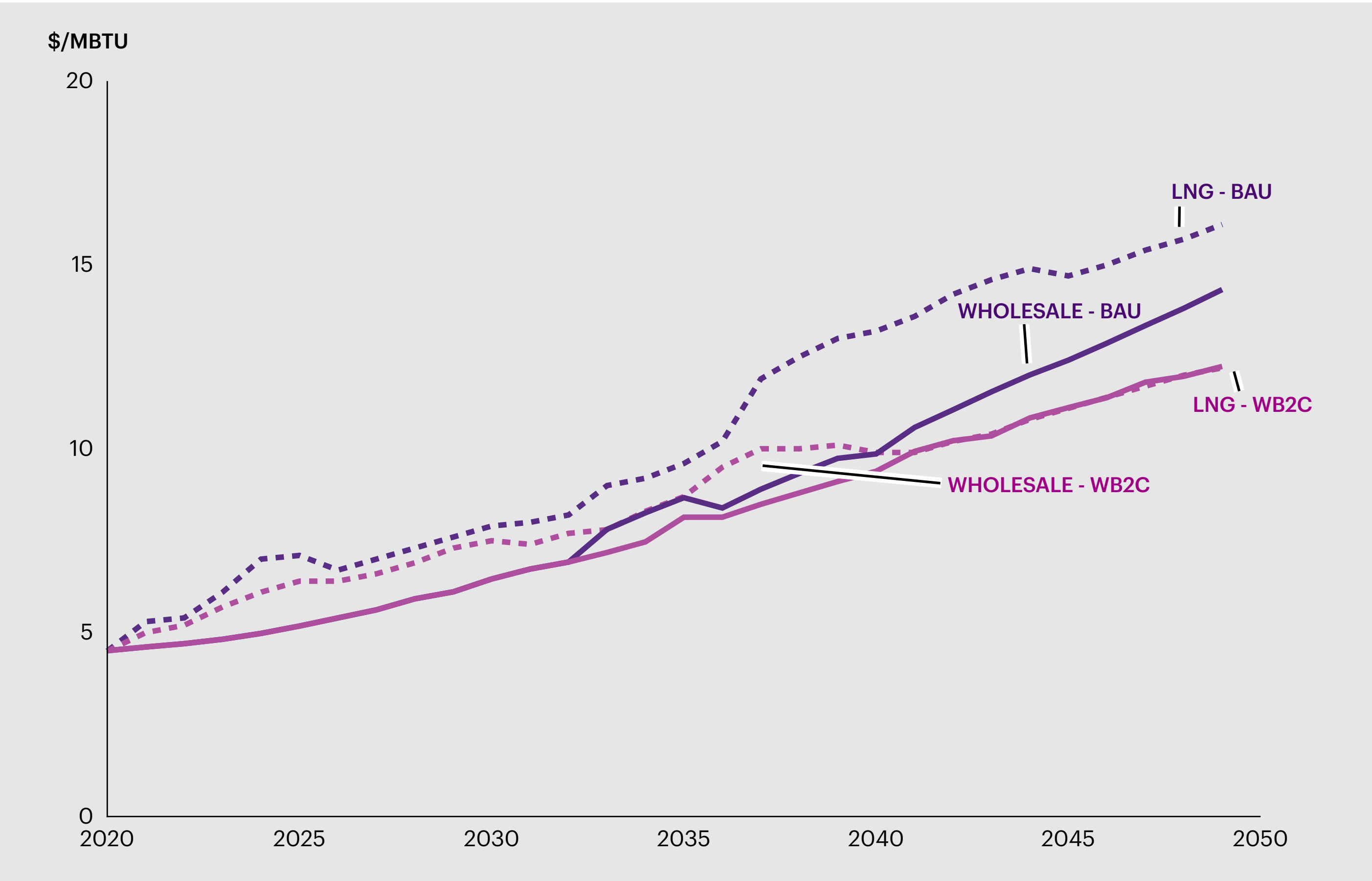
The prospect of significant offshore volumes ramping up towards the end of the decade, combined with the elevated but volatile nature of LNG prices, is likely a major headache for existing and potential new investors in Colombia's LNG terminal capacity, given the uncertainty of future volumes. Volume uncertainty will likely create significant challenges for any new financing. In turn, this could create further uncertainty around Colombian security of gas supply in the second half of the 2020s. During this period, our analysis shows that Colombia could face an annual deficit in supply of between 1-3 bcm, without increases in import capacity.

3.2.3.3. Climate transition risk exposure by field and region

Among firms in the Colombian natural gas value chain (from producers, importers, LNG terminals, transmission and distribution pipelines, storage and utilities), our analysis shows that climate transition risk could be spread between producers, importers and LNG terminals to different degrees depending on future contracting and financing arrangements.

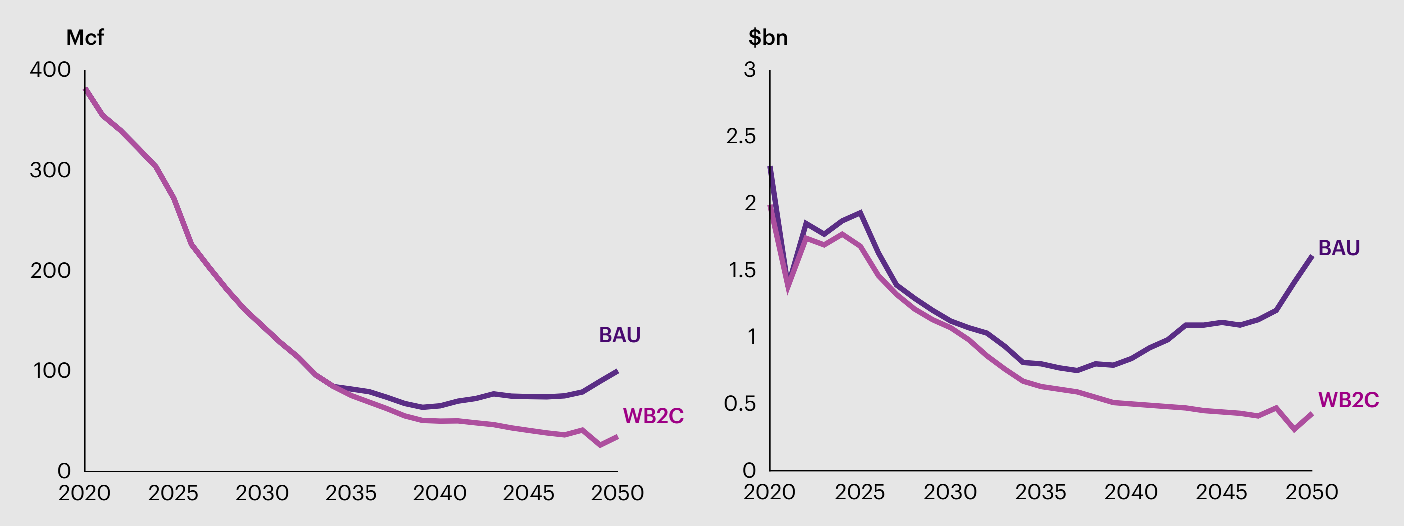
In the scenario without shale production, Colombian domestic producers would face maximum climate transition downside risk of **$2.2 billion**, resulting from the effect of lower prices in a WB2C scenario[195]. Domestic producers would lose only 3% of cumulative volumes, with only the Meta department losing some material volumes to importers in a WB2C scenario (9% of BAU).

Figure 17: **Colombian wholesale gas prices vs. spot LNG prices (global BAU and WB2C scenario)[194]**



193. Source: https://www.fitchratings.com/research/corporate-finance/colombian-gas-utilities-are-insulated-from-high-international-prices-02-05-2022
194. Source: WTW and UniAndes analysis
195. This assumes a gradual transition of domestic prices to import parity

Figure 18: **Volume vs. value at risk for Colombian conventional natural gas production.**[196] **Left: Volume. Right: Revenues**



3.2.3.4. Climate transition risk exposure of infrastructure assets

Colombia's existing LNG terminal at Cartagena is also likely to face an element of climate transition downside while the terminal's future economic life, regardless of the global transition, could be vulnerable to uncertainties relating to the decisions on Buenaventura and offshore gas.

Cartagena's operators stand to benefit in during the 2020s from declines in onshore production and growing domestic demand. However, the potential entry of offshore production in the 2030s could, depending on the cost of developing those fields, significantly reduce throughput during the 2030s. The terminal operators also face uncertainty around the potential future terminal at Buenaventura, although the longer an investment decision in the latter is delayed, the most likely it seems that Colombia would seek to pursue an expansion at Cartagena in the first instance.

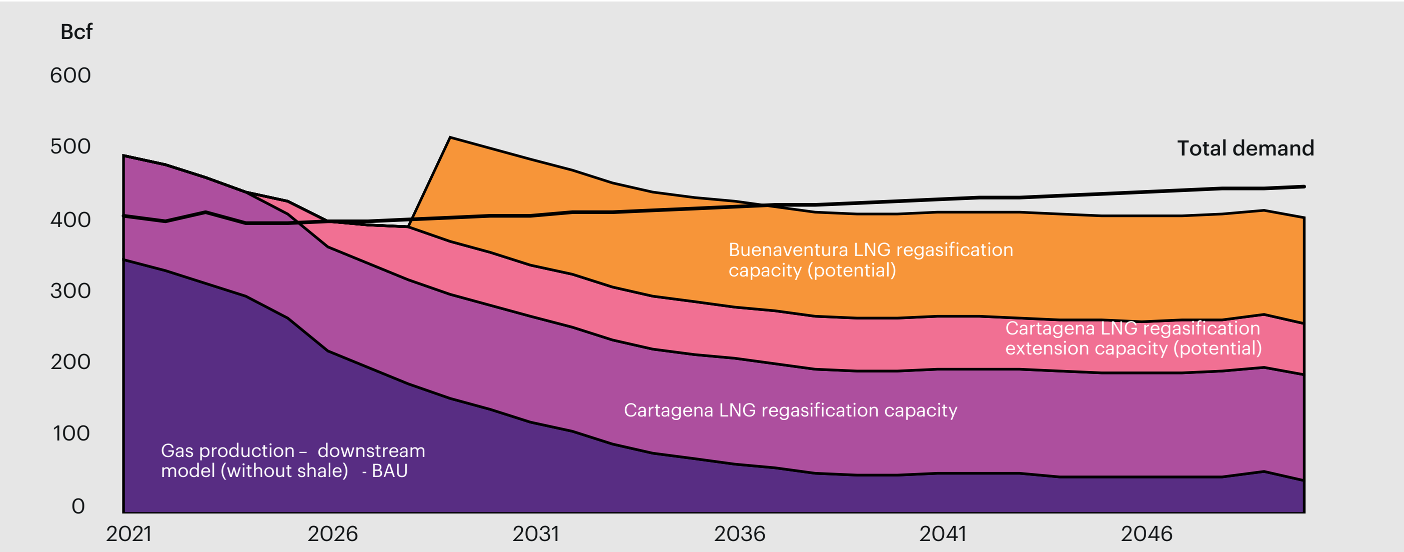
As illustrated in figure 19, without additional offshore production, there looks like a solid case for expanding LNG capacity.

It is a very different picture if you assume the potential development of Gorgon-2.

However, the very uncertainty about the timing and volume of potential additional offshore gas production could create challenges for the financing of any additional LNG capacity, which, in turn, could create a supply adequacy issue in the second half of the 2020s.

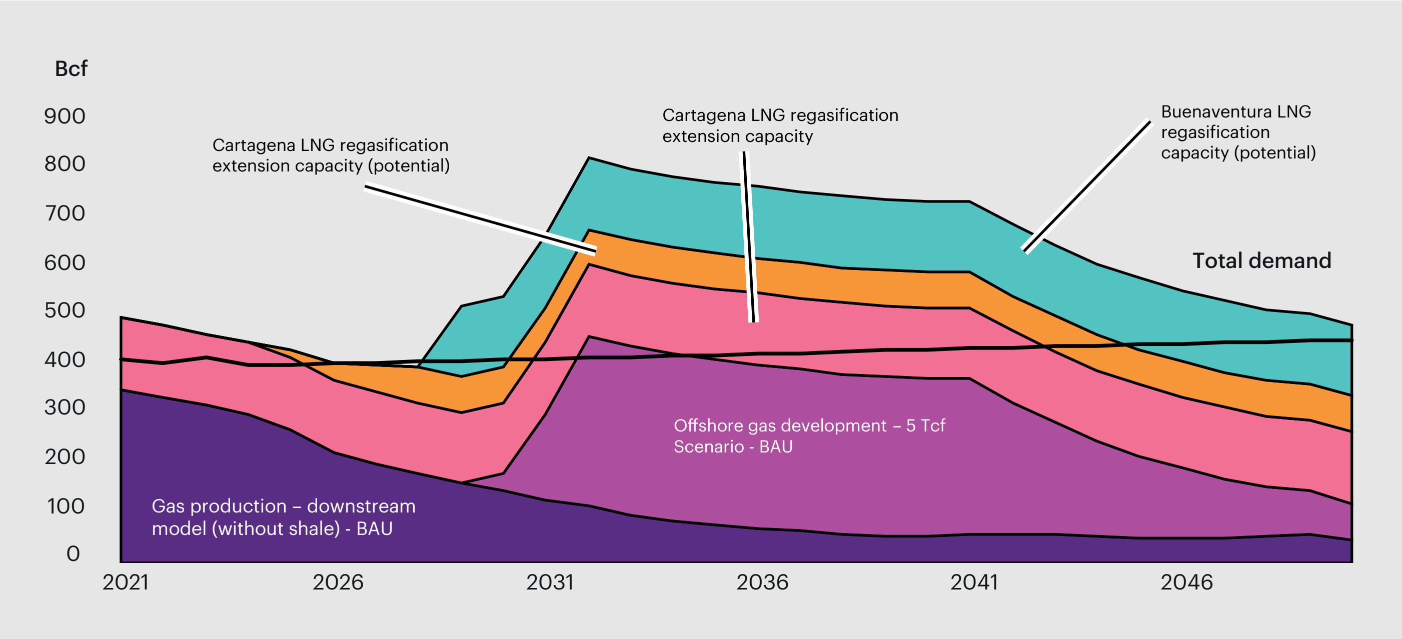
Whether at Cartagena or at Buenaventura, any investment in new LNG infrastructure would face stranding risk in an accelerated domestic transition of the sort explored in chapter 5.

Figure 19: **LNG import capacity adequacy without offshore production**[197]



196. Source: WTW and UniAndes analysis
197. Source: WTW and UniAndes analysis

Figure 20: **LNG import capacity adequacy with offshore production**[198]



3.2.3.5. Climate transition risk exposure of rest of value chain

Our analysis suggests that other parts of the natural gas value chain – namely transmission and distribution pipeline operators, storage operators and utilities – are likely to face much more limited risk from the global transition. We expect the transmission owners (Promigas and TGI) and distribution operators (Vanti, Promigas, Gases del Caribe, EPM, Alcanos) to remain subject to rate of return regulation, largely protecting the owners from both price and volume risk.

Unless a domestic transition were to affect domestic demand (see chapter 7), we would expect storage operators to face limited risk. Utilities and other gas marketers should be mostly protected against the impact of rising prices in both BAU and WB2C scenarios, provided the current regime of cross-subsidies between customer groups remains, supplemented by public budget support, where necessary. If these price subsidies were to be removed, utilities would likely face increasing credit risk, particularly in a BAU scenario, unless customers in vulnerable groups were supported by alternative forms of social transfers.[199]

3.2.4 Metallurgical coal, metallurgical coke, iron ore and steel products

3.2.4.1. Global climate transition dynamics for metallurgical coal, coke, iron ore and steel

Metallurgical coal is primarily used to produce metallurgical coke which is used in blast furnace-basic oxygen furnace (BF-BOF) steelmaking process as a reducing agent, separating oxygen and other impurities from iron ore. As the BF-BOF is currently the dominant steel producing method globally[200], there is significant demand for metallurgical coal and coke, though most metallurgical coke is made in onsite or "captive" coking plants. A much smaller proportion of global demand for metallurgical coke is serviced by independent coking plants. These plants also sell coke in much smaller amounts to non-steel industries, including chemicals[201], agribusiness[202], to electric furnaces[203], to metal smelters[204] and industries that use graphite, including the battery industry[205].

198. Source: WTW and UniAndes analysis
199. Source: https://www.imf.org/en/Publications/CR/Issues/2019/11/18/Colombia-Technical-Assistance-Report-Reforming-Energy-Pricing-48819
200. According to the IEA, BF-BOFs made up around 70% of global crude steel production in 2020, Current market share of BF-BOF, with around 5% gas-DRI electric arc furnaces and the rest in scrap EAFs, such as the ones that predominate in Colombia. Source: https://www.iea.org/reports/iron-and-steel-technology-roadmap
201. By-products from the coke making process can be refined within coking plants to make commodity chemicals including benzene. (Source: https://www.ncbi.nlm.nih.gov/books/NBK304422/#:~:text=The%20carbonization%20by%2Dproducts%20are,of%20other%20chemicals%20and%20materials.)
202. Coke and coal are also used in small amounts in Colombia for drying grain and other food products, such as tobacco
203. Coke is used in the production of alloys, as a reducing agent (so it functions in a similar way with alloy production to its use in producing steel
204. Source: https://www.academia.edu/4288405/CARTILLA_CARBONES_Y_COQUES
205. Graphite electrodes are currently an important part of electric arc furnaces, with around 3kg of graphite required to produce 1 tonne of steel (source: https://www.reuters.com/article/china-steel-graphiteelectrode-idINKCN1BW0RW). Graphite is also used in lithium ion battery manufacturing, suggesting a likely significant future increase in demand for graphite in a WB2C scenario. If naturally occurring graphite is insufficient to meet demand from battery makers, this could increase demand for synthetic graphite, which can be made from "needle coke", which, in-turn, can be made from the coal tar by-products of the coking making process (source: https://www.televisory.com/blogs/-/blogs/can-lithium-ion-anode-demand-for-needle-coke-reduce-availability-for-electrode-players-). The size of this potential market for coke producers will also be impacted by the availability of natural graphite supply (source: https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/energy-transition/021622-feature-graphite-supply-a-concern-in-meeting-growing-battery-demand)

The multiple use cases of coke (and hence metallurgical coal) complicate the analysis of climate transition risk for these products and a more comprehensive picture would require an analysis of climate transition pathways for each of these use industries. However, based on discussions with Colombian officials, we understand that iron and steelmakers (both in Colombia and in major export destinations, such as Brazil, Mexico, and Chile) are currently by far the primary purchasers of Colombian coke and so we focus on the impact of deep decarbonisation in steelmaking as a driver of climate transition risk for Colombian coke producers. In chapter 4, we highlight the uncertain potential for coke producers to diversify their end markets.

BF-BOF plants are significantly more carbon intensive[206] than the other current steelmaking process (the scrap-based electric arc furnace or "scrap EAF"), meaning that their market share would decline in a WB2C scenario compared to a BAU scenario. However, scrap EAF plants would not be able to replace BF-BOF plants entirely, as the amount of steel they can produce is capped by the limited (through growing) availability of steel scrap (used as primary feedstock in scrap EAFs) and the fact that the steel that they typically produce construction grade steel and not the highest quality steel required for some industrial applications[207].

In our WB2C scenario where the production of "primary steel" is deeply decarbonised, unabated BF-BOF plants would be phased out by 2050. Where countries have access to abundant, low-cost metallurgical coal resources (particularly in China), we would expect to see some new BF-BOFs equipped with CCUS[208]. In places without metallurgical coal reserves but with significant lower grade iron ore reserves (such as India), innovative smelt reduction techniques may be used, also equipped with CCUS[209], although the technology is still in its infancy.

The other contender that we expect to be deployed at scale is direct reduction of iron (DRI), i.e., the use of alternative reducing agents other than coke. This process is currently most common in the Middle East, where the abundance of natural gas means that it is a cheaper option than a BF-BOF process based on imported metallurgical coal. To be viable in a WB2C scenario, gas based DRI plants would need to be retired or equipped with CCUS. DRI has more promise as a scaleable technology when using hydrogen as a reducing agent. "Green hydrogen", produced by electrolysis from renewable electricity and water, is currently experiencing an investment boom[210], driven by the promise of fuelling clean industrial processes, like steel production, without the added cost of CCUS equipment. "Blue hydrogen", produced by a process of steam methane reforming[211], equipped with CCUS, has also been touted as an option, particularly in the Middle East and other countries with abundant natural gas reserves (e.g., Australia).

The relative market shares of the above steelmaking technologies will also impact the iron ore market. While we expect demand for the highest-grade iron ore – "lump" – to remain robust, a shift in market share from BF-BOF processes to DRI-based processes could see a shift in demand from sinter fines to pellets (an agglomerated product made from lower quality ore than sinter fines). In markets, like Colombia, with captive iron ore resources, the quality of the domestic ore could also play an important role in determining the likely low-carbon trajectory.

Our WB2C scenario for the global steel industry and its primary input materials shows lower demand growth than in BAU (because of increased steel recycling and circular economy strategies), and faster decarbonisation of steelmaking processes. Table 23 shows our scenarios for steel product demand, while figure 21 sets out our view of the most likely dominant low carbon steelmaking methods in a WB2C scenario.

Table 23: **Steel product demand scenarios (global)**[212]

		2019	2025	2030	2035	2040	2050
BAU	Mt	1,821	1,988	2,095	2,214	2,321	2,524
WB2C	Mt	1,821	1,972	1,995	2,022	2,035	2,030

206. According to the IEA (2020), producing one tonne of crude steel via the BF-BOF method results in around 2.2 tonnes of CO2. Gas based DRI-EAF produce around 1.4 tonnes of CO2. The carbon intensity of scrap based EAFs depends on the carbon intensity of the electricity used, but on average results in slightly more than 0.3 tonnes of CO2 per tonne of crude steel.
207. A key problem with recycling steel scrap is contamination with other elements, particularly with copper. This contributes to what ETC authors call "downcycling" i.e. the downgrading of recycled steel, compared to primary steel, for use in a smaller group of activities whether the chemical content of steel is less important (for example, as rebar for construction steel). Source: https://www.energy-transitions.org/wp-content/uploads/2020/08/ETC-sectoral-focus-Steel_final.pdf
208. China's early experience with CCUS in industry may make it particularly well-placed to implement CCUS at BF-BOF plants, particularly if other forms of primary steel production (i.e. smelt reduction) are delayed or turn out to be very expensive
209. The use of pure oxygen (as opposed to air) in the HlSarna process leads to a relatively high purity of CO2 stream, meaning that it is relatively low-cost to capture (Source: https://www.globalccsinstitute.com/news-media/insights/ccs-a-necessary-technology-for-decarbonising-the-steel-sector/)
210. See: https://www.forbes.com/sites/mikescott/2020/12/14/green-hydrogen-the-fuel-of-the-future-set-for-50-fold-expansion/
211. The following article explores the potential competition and trade-off between green and blue hydrogen https://cleanenergynews.ihsmarkit.com/research-analysis/german-refineries-kick-off-complex-green-hydrogen-switch-.html
212. Source: WTW in-house analysis

Figure 21: **Implications of the global low carbon transition for steel and its primary input materials**[213]

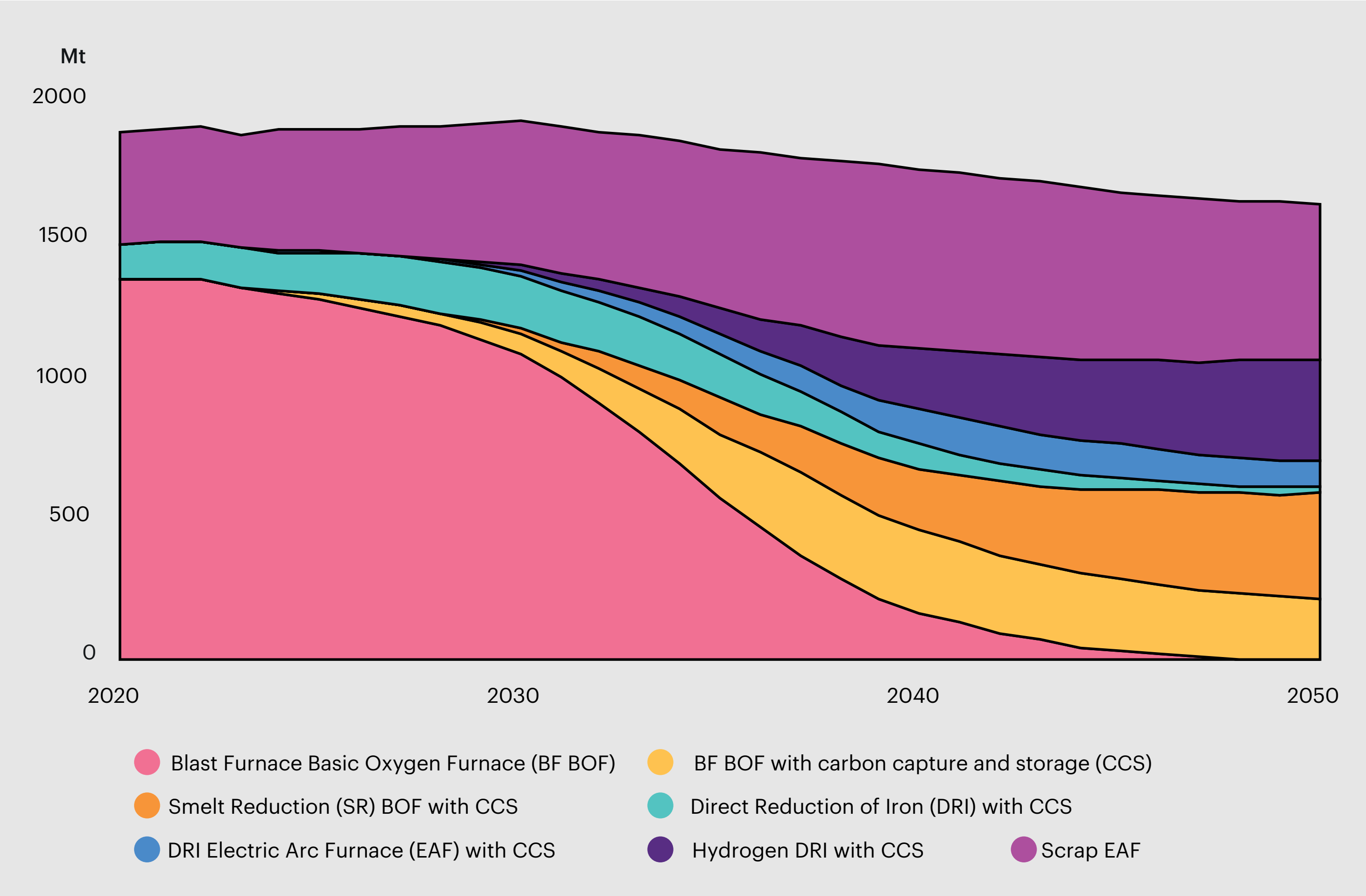
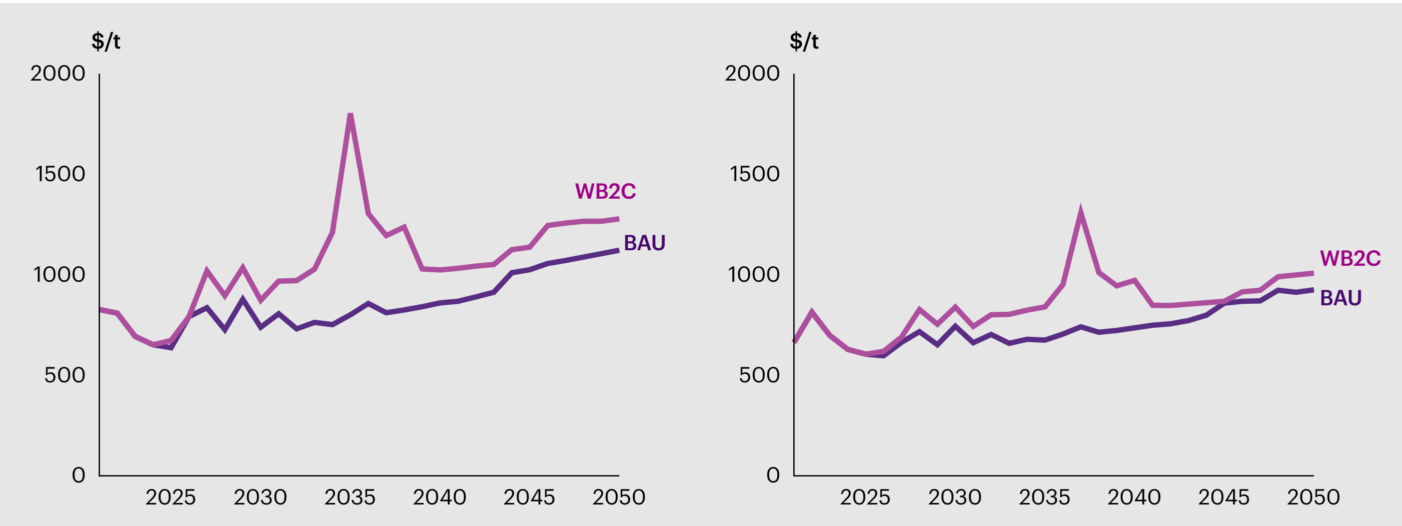


Figure 22: **Long and flat steel price scenarios (global)**[214]



Our projected pricing for both long and flat products rise faster than in BAU, to account for the incremental capital cost for the more extensive replacement existing steelmaking capacity with new low carbon capacity.

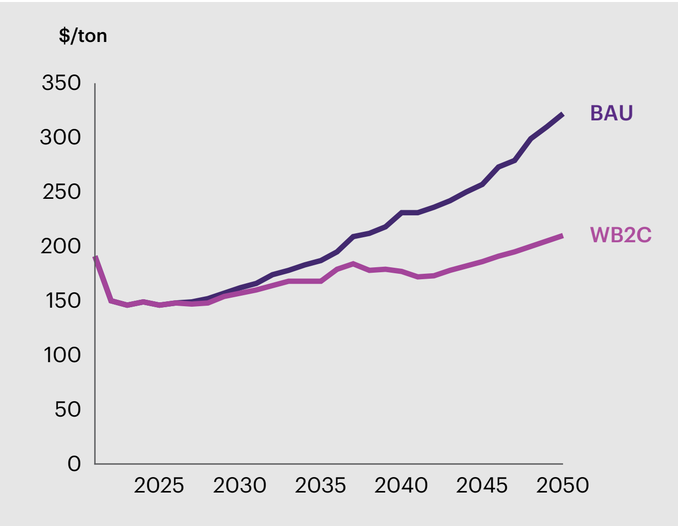
Faster decline in the market share of BF-BOF steel processes (both unabated and with CCUS) in a WB2C scenario compared with a BAU scenario results in weaker demand and prices for metallurgical coal, metallurgical coke and iron sinter fines.

213. Source: WTW and UniAndes analysis. "SR BOF CCS" relates to innovative smelt reduction technologies
214. Source: WTW analysis

Table 24: **Seaborne metallurgical coal and metallurgical coke demand scenarios (global)**[215]

		2019	2025	2030	2035	2040	2050
BAU Coal[216]	Mt	926	1,009	1,044	980	898	951
BAU Coke[217]	Mt	20	22	23	21	20	23
WB2C Coal	Mt	926	997	956	840	578	413
WB2C Coke	Mt	20	22	19	18	14	10

Figure 23: **Metallurgical coal price scenarios (global)**[218]



Unlike with thermal coal, the war in Ukraine appears to have had limited short-term impact on metallurgical coal, coke, iron ore and steel prices. This is largely because the dominance of China as producer in the global steel market meaning that Chinese supply provides the marginal steel products and Chinese demand absorbs the marginal tonnes of coal, coke, and iron. Near term prices are down, compared with our BAU scenario, due to concern about China's post-COVID economic recovery and the dampening impact of US dollar strength on global demand.

3.2.4.2. Climate transition risk for Colombian metallurgical coal and coke producers

Compared with thermal coal, Colombia's produces a much smaller amount of metallurgical coal and anthracite (in 2019, it produced 5mt of metallurgical coal vs. 70mt of thermal coal), but coal has become a particularly profitable segment of the industry for large producers, such as Coquecol and Carbomas, who mostly export the coal after converting it to metallurgical coke. Colombia exports 80% of the coke it produces, with the rest (c. 1 mtpa) used domestically, including as a reducing agent in the Paz del Rio steelworks in Boyacá province. Colombian miners also export a much smaller tonnage of metallurgical coal, averaging around 250,000 tonnes in recent years.

In 2021, Colombia was the third largest player in the export of metallurgical coke after China and Poland[219]. Colombian coke producers sell to a relatively small niche in the global steel market[220] – to steelmaking plants with BF-BOF processes that do not have onsite or captive coke production. In this market, most of the demand comes from China, India, and Europe, although Colombian producers obviously have competitive advantages in selling to plants in the Americas.

Based on the assumption that Colombian coke production is predominantly sold to steelmakers, we estimated climate transition risk downside exposure for metallurgical coke and coal exports at a maximum of **$2.8 billion**, arising from a combination of lower prices in a WB2C scenario and lower volumes (see table 24) due to accelerated phase-out of BF-BOF processes in Europe and Brazil. We focus on those two regions as particularly well placed to be leaders in the decarbonisation of primary steelmaking, given the former's high climate ambition and high carbon prices and the latter's strong

215. Source: WTW and UniAndes analysis
216. This line represents coal traded internationally that is primarily used to make coke either in on-site coking facilities in steel production facilities or at standalone coke production facilities
217. This line represents coke traded internationally. The small amount, compared with metallurgical coal traded volumes, is indicative of the fact that steel production facilities using the BF-BOF method typically have on-site coking facilities rather than buying in coke.
218. Source: WTW and UniAndes analysis
219. The following article explores Colombia's role in the global coke market: https://thenationview.com/economy/25010.html
220. We understand, anecdotally, that Colombian coke producers sell small amounts to non-steel industries

Table 25: **Colombian metallurgical coke export volumes, global BAU vs. WB2C scenarios**

		2019	2025	2030	2035	2040	2050
BAU	Mt	3.2	3.9	4.1	3.8	3.6	4.1
WB2C	Mt	3.2	3.9	3.4	3.2	2.5	1.8

potential competitive position in producing steel with the H2-DRI process (namely, its abundant iron ore reserves, low renewable energy costs, and experience with DRI processes).

Given Colombia's relatively high-quality coal and relatively small position in the global metallurgical coal market, climate transition risk exposure is likely to be driven principally by prices (as opposed to volumes). Coke, while also facing price risk, is more likely to face volume downside, although not until the first half of the 2030s for European and North American markets ex-Mexico and second half of the 2030s for Brazil and Mexico.

In the long run, producers in the Colombian iron/coke/steel value chain (and even policymakers with a focus on the sector) face much greater uncertainty about global decarbonisation trends than those in the thermal coal value chain, given the greater uncertainty about the shape and speed of the climate transition that the global steel industry will undertake.

Colombian metallurgical coal and coke producers could not take maximum advantage of elevated global prices in 2021 because infrastructure constraints mean significant cost is incurred to transport product to port in Colombia.

We understand that policymakers are actively considering the construction of a rail line from the centre of the country to Buenaventura, which could potentially enable Colombian producers to increase exports, at least temporarily. However, our analysis suggests that this is unlikely to be a long-run growth opportunity, given that Colombia already effectively supplies the market for coke in the Americas and has close to 20% of global market share as it is[221]. In fact, material new infrastructure investments whose economics are dependent on transporting coke or coal could increase climate transition risk for Colombia, unless the investments have a short payback period, or the operators have an active plan to diversify cargos away from products facing climate transition risk.

3.2.4.3. Climate transition risk for Colombian iron and steel producers

Despite declining prices for coke and some iron ore grades, our analysis shows that Colombia would face a faster increasing steel import bill in a WB2C scenario than a BAU scenario, because of higher prices needed in the former to support accelerated investment in decarbonising steel processes. The overall impact of the higher prices to steel consumers (in most cases, the buyers of new buildings), would total around **$2 billion** although we do not expect prices to have much of an impact on demand, given that viable alternative materials with similar properties are not easily available.

The position for Colombia's steelmakers is somewhat more ambiguous. On the one hand, since most steel products in Colombia are priced at import parity, higher steel prices in a WB2C scenario means that all Colombia's steel makers could be significantly better off, provided that Colombia follows a slow industrial decarbonisation path (the NPV of the potential gain is between **$10 billion and $14 billion**). On the other hand, the additional costs that Colombian steelmakers could face in an accelerated Colombian deep decarbonisation plan (as discussed in chapter 5) could significantly eat into this.

Table 26: **Colombian long (rebar) steel demand, production, and imports (global BAU and WB2C)**[222]

		2019	2025	2030	2035	2040	2050
Demand	Mt	2.1	2.9	3.4	4.1	4.8	6.8
Colombian production	Mt	1.3	2.1	2.1	2.1	2.1	2.1
Imports	Mt	0.8	0.8	1.3	2.0	2.7	4.7

221. It may have some limited upside, given that one of its previous competitors was Ukraine – though here it will be
222. Competing with Poland, another large supplier with the advantage of geography

Rising domestic steel demand, coupled with higher prices, could create an attractive investment case for expanding Colombian steel producing capacity. According to a recent study by the International Energy Agency[223], the levelised cost of most steel making methods today is lower than that the import price of long steel to Colombia. With steel prices expected to go up and learning effects due to bring down the capital cost of DRI processes, the economics will only likely improved, especially if Colombia is able to produce green hydrogen by 2030 at the prices quoted in the hydrogen roadmap.

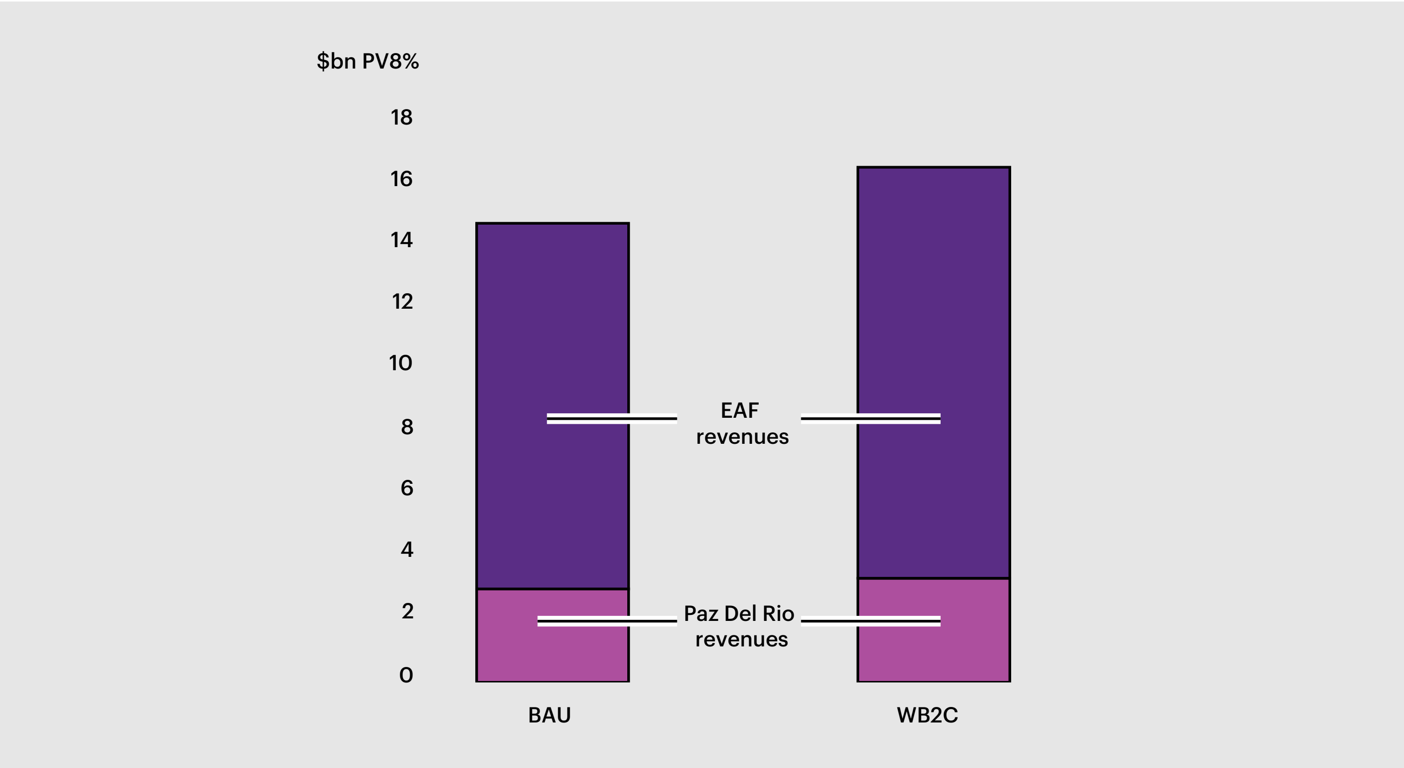
The optimum type of new steel-making capacity they decide to add will depend on Colombia's future industrial strategy. For example, Colombian wind turbine production would require high quality electrical steel (which would require continued primary steel production). There will clearly be scope for additional scrap-based electric arc furnaces, similar to Ternium's new 440ktpa Palmar de Varela plant, provided that scrap availability continues to rise. Expansion of Paz del Rio would likely be the cheapest way to add BF-BOF capacity, but this would significantly increase Colombian emissions (unless equipped with carbon capture) and expose the owners to incremental climate transition risk. However, if Colombia decides to take the industrial opportunities offered by the low carbon transition (as set out in chapter 5), there may be sufficient demand to justify investing in a new source of primary steel production.

Depending on the size and quality of Colombia's iron ore reserves, Colombia may have an attractive option to build a H2-DRI plant, which could act as anchor source of demand for the nascent hydrogen production industry. However, limited financial capacity of Colombian steelmakers and their owners could be a barrier to the development of new capacity[225] .

3.2.4.4. Climate transition risk exposure by plant and region

Over 80% of Colombia's steel is currently produced through the electric arc furnace (EAF) method, with the remainder coming from the Paz del Rio BOF-BF plant. The EAF producers produce steel at much higher marginal costs than Paz del Rio[226], with lower margins meaning they are more susceptible to import substitution depending on how global prices or domestic power costs shift. The global climate transition, however, should help to boost the margins of all domestic producers in the long run, providing greater resilience from other structural changes in steel markets, for domestic steel producers. Figure 24 shows how revenue increase in a WB2C across both types of assets, with EAF costs much better covered by WB2C scenario revenues than BAU. Transition risk upside between these assets amounts to over $2bn, with the rest of the upside available to be captured by additional capacity which could be built to support strong domestic steel demand growth in the future.

Figure 24: **Revenues for existing steel production assets in BAU and WB2C scenarios**



223. Source: WTW and UniAndes analysis
224. Source: https://www.iea.org/reports/iron-and-steel-technology-roadmap
225. DRI processed require pelleted (and hence pellet grade) iron ore. We were unable to find public information about the quality of Colombia's iron ore reserves.
226. Colombian plants owned by international parent companies, such as Gerdau and Ternium, might have greater access to capital. At the time of publication, Gerdau held investment grade credit ratings from S&P, Moody's, and Fitch, suggesting a certain financial capacity to make new investments (source: https://ri.gerdau.com/en/financial-information/ratings/)

Table 27: **Northern port exposure to coal-related external transition risk (volumes in millions of tonnes, 2022-2050)**

	% total revenues from coal 2021[227]	BAU volumes	WB2C volumes	Volume at risk (%)
Santa Marta	40%	92	36	60%
Barranquilla	20%	70	59	16%
Cartagena	36%	17	16	6%
Puerto Brisa	69%	421	46	89%
Total Northern Ports	33%	600	157	74%

3.2.4.5. Climate transition risk exposure of infrastructure assets

While metallurgical coke exports would decline more slowly in a WB2C scenario than thermal coal exports, the downside risk to the sector represents an additional source of downside risk to Colombian ports.

In recent years, Baranquilla has been the major port used for the export of coke (3.2mt in 2020), supported in the north of the country by Cartagena, Puerto Brisa, and Santa Marta (collectively 0.9mt in 2020). By contrast, less than 200,000 tonnes were exported through Buenaventura in 2020. A new rail line to Buenaventura, would be exposed to climate transition risk unless it had diversified cargo or a medium-term plan to diversify it away from coal.

3.3 Conclusion

Colombian producers face downside climate transition risk from a range of global transitions affecting major current Colombian export sectors, such as thermal coal, metallurgical coke (via its customers in the steel sector), crude oil, oil products and natural gas. Colombian steel producers also stand to earn higher revenues in the short-term if global steel markets transition faster than the sector in Colombia. In addition, lower liquid fuel, and natural gas prices in a WB2C scenario would also create gains for Colombian consumers of those products. As we explore in chapter 5, this is a potential source of value that could be useful in helping to mitigate climate transition risk. New potential export sectors, such as copper and others explored in chapter 5, could also provide upside. However, the timing of these downsides and upsides do not offset one another, nor will the losses and gains naturally accrue to the same people.

Table 28: **External climate transition risk for Colombian value chains by decade, no shale, no offshore gas (NPV)[228]**

	Today to 2030	2030s	2040s	Total
Thermal coal	-19.2	-17.0	-6.5	-42.7
Metallurgical coal and coke	-0.5	-1.0	-1.3	-2.8
Crude oil and oil products	-16.9	-14.4	-9.3	-40.6
Natural gas	-0.7	-0.5	-1.1	-2.2
Total downsides	*-37.3*	*-32.9*	*-18.2*	*-88.3*
Steel products	4.1	6.1	4.0	14.2
Total upsides	*4.1*	*6.1*	*4.0*	*14.2*
Total net	**-33.2**	**-26.8**	**-14.2**	**-74.1**

227. We did not have access to asset-level cost data about Paz del Rio, but rather derived this conclusion based on asset-level information about other similar plants provided in the CRU database.
228. We calculated the numbers in this column, by comparing the amount of coal port handling revenue (calculated using port costs and volumes from coal and coke commodity models) with total revenue per port (source: EMIS). We corroborated the quantitative findings with secondary literature on the relative reliance of different ports on coal and coke. (Sources: https://www.supertransporte.gov.co/documentos/2021/Febrero/Puertos_04/BOLETIN-TRAFICO-PORTUARIO-2020.pdf and https://aniscopio.ani.gov.co/puertos-public/ficha-proyecto)

If the Colombian government wishes to avoid the potentially systemically significant consequences of external transition risk, it needs to factor into policy planning not only the material quantum of the risk, but also the question of timing. As set out in table 27, 45% of the total downside could crystallise in this decade, with 36% in the 2030s and the rest in the 2040s. This is consistent with our hypothesis that external transition risk is likely to materialise earlier than domestic transition risk

In this chapter, we have also highlighted practical uncertainties about the challenges facing both natural gas and metallurgical coke industries, relating to the cost and availability of offshore Colombian gas resources and climate transition pathways for non-steel consumers of coke.

Successful deployment of offshore gas resources would increase climate transition risk for natural gas producers and potentially, infrastructure providers, but it could reduce Colombia's reliance on LNG importers. However, even a very successful ramp-up of offshore gas resources is unlikely to offset a structural decline in Colombia's fossil fuel related trade balance. Whether in BAU or WB2C, shale or no shale, prolonged or curtailed war in Ukraine, Colombia appears to be heading from its previous position where a fossil fuel trade surplus plugged a large gap in Colombia's current account, to one where the industries could become the largest drag on Colombia's current account. If left unmitigated, this could have serious knock-on macroeconomic impacts that are explored in chapter 4. The analysis set out in chapter 5 proposes recommendations, which would help Colombia to tackle these issues in the urgent and proactive manner that their materiality would demand.

Table 29: **External climate transition impact on to Colombia's trade balance (nominal $bn, no shale, no offshore gas)**[229]

	BAU			WB2C		
	2020s	2030s	2040s	2020s	2030s	2040s
Thermal coal	54.5	45.1	33.7	27.3	2.7	0.2
Metallurgical coal and coke	10.7	12.9	16.3	9.9	9.6	7.1
Steel products	-5.5	-14.5	-32.1	-5.0	-15.0	-25.0
Crude oil and oil products	44.3	-38.7	-143.7	33.2	-30.4	-68.4
Natural gas	-10.9	-35.3	-57.8	-10.2	-30.6	-44.4
Total	**93.1**	**-30.5**	**-183.6**	**55.2**	**-63.7**	**-130.5**

Table 30: **External climate transition impact on Colombia's trade balance (nominal $bn, with offshore gas)**[230]

	BAU			WB2C		
	2020s	2030s	2040s	2020s	2030s	2040s
Thermal coal	54.5	45.1	33.7	27.3	2.7	0.2
Metallurgical coal and coke	10.7	12.9	16.3	9.9	9.6	7.1
Steel products	-5.5	-14.5	-32.1	-5.0	-15.0	-25.0
Crude oil and oil products	44.5	-32.6	-73.3	33.2	-30.4	-68.4
Natural gas	-10.6	-3.0	-33.6	-9.2	-5.8	-22.7
Total	**97.4**	**7.9**	**-89.0**	**56.2**	**-38.9**	**-108.8**

229. Source: WTW and UniAndes analysis
230. Source: WTW and UniAndes analysis

4. Climate transition risk allocation at micro- and macro-levels

Key messages:

1. Based on the instruments that allocate value and risk in the Colombian economy today (royalties, taxes, ownership etc.), Colombian firms would bear 72% (or $64 billion) of the downside risk, with the rest being split between local and national governments.

2. Ecopetrol faces the largest absolute downside through its exposure to oil and gas prices. However, compared with today's size / market value, independent oil and gas producers and coal mining companies face a much more severe challenge. If they recognise these risks, firms have options to protect themselves via diversification, although coal miners have the least time.

3. The risk mitigation actions of firms in a WB2C scenario (including the potential early closure of coal mining) are likely to shift downside risk onto workers, communities, and local governments. As well as putting between 25,000-30,000 direct jobs (and multiples higher indirect jobs) at risk, a structural decline in hydrocarbon royalties would create a major challenge for the local government funding system

4. As effective risk bearer of last resort, the national government balance sheet could face nearly half of the downside risk, given that workers, local governments, and small firms have limited risk-bearing capacity and hence will need support

5. If left unmitigated, external climate transition risk would put at risk Colombia's sovereign credit rating, creating a series of additional macroeconomic downsides and threats to financial stability on top of the $88 billion in downside risk

4.1 Introduction

In chapter 3, we set out the results of the analysis of external transition risk in key Colombian commodity producing sectors, showing that, if unmitigated, the country might face downside risk amounting to **$88 billion** between 2022 and 2050. However, the practical implications for Colombia of that quantum for Colombia are highly dependent on how that risk is distributed between parts of the Colombian economy, society, and the financial system. This chapter sets out the results of our research and analysis about the "transmission mechanisms" by which climate transition risk in Colombia could move from firms in the real economy sectors reviewed in chapter 3, to other parts of the Colombian system, including the public balance sheet. From these results, we also draw conclusions about the broader significance of these risks and the threat that, if left unmitigated, they may pose to Colombia, including for the sustainability of public finances and the long-term viability of an economic model founded on extractive industries.

The chapter splits the process of climate transition risk allocation into four, according to the mechanisms that transfer risk. We recognise that, like any other economic or financial risk, climate transition risk is dynamic and will be likely to move around the Colombian system as global and Colombian deep decarbonisation processes play out. We split the dynamics of climate transition risk within Colombia in four sequential steps, described below. For each of these steps, where possible, we have quantified the size (in net present value terms) of the risk allocation or risk transfer and specify the economic groups to whom risk is likely to be transferred.

1. **"Explicit" risk allocation,** or the initial split of climate transition risk via formal mechanisms that exist today. These mechanisms allocate risk and value (mostly) unambiguously. Examples include ownership, contracts, and taxes. We explore these issues in section 4.2.

2. **Strategic behaviour and implicit risk transfer.** This form of risk allocation arises from the actions of those seeking to manage their risk. Parties that face risk under step 1 may, if they have access to capital and/or knowhow, seek to transfer risks on to other parties to protect themselves. A good example would be companies seeking to divest climate transition risk-exposed assets to those with less of an awareness of the magnitude of risks that remain poorly understood or under-priced. These issues are explored in section 4.3.

3. **Contingent liabilities.** Where climate transition risks crystallise and fall on parties with limited risk-bearing capacity (for example, coal mining workers or highly leveraged firms), those parties may fall into financial distress. Parties that face material explicit risk and have limited scope to transfer this or otherwise mitigate it themselves, may easily find themselves in this position. This can sometimes result in unbudgeted for or unprovided for costs, particularly for financial institutions and governments. These issues are explored in section 4.4.

4. **Systemic risks.** Climate transition risks may be so large and that, if they are not well allocated that they can cascade in chaotic fashion across an economy or financial system. Examples include the macroeconomic second round effects of a persistent decline in the external balance or the implications of declining public debt sustainability for the sovereign credit rating and the implications of a declining sovereign credit rating for financial stability. These issues are explored in section 4.5.

We performed the analysis of explicit risk using desk research into typical mechanisms for allocation risk and value in market economies and how they are applied in Colombia. Where possible, we corroborated interpretations with original policy, regulatory, and where possible, contractual documents. Analyses of other forms of risk transfer are necessarily more speculative and were informed by extensive interviews with Colombian stakeholders, in addition to further specific analyses, including of the impact on sovereign debt and potential macroeconomic and financial system-level implications of climate transition risk in Colombia.

4.2 Explicit risk allocation

4.2.1 Summary

In a world where regulation, policy, and contracts could not be changed and where companies were allowed to fail with no wider impact on workers or the economy, Colombian external transition risk would be split between firms and their suppliers, workers and shareholders, local and national government. We identified as primary instruments of explicit risk allocation regaliás, taxes (levied at local and national level), financing arrangements (including ownership).

Table 31: **Explicit risk allocation: producing value chains**[231]

	Firms	National government	Local government	Total
Thermal coal	-34.1	-4.4	-4.2	-42.7
Metallurgical coal and coke	-2.7	-0.1	-0.1	-2.8
Crude oil, oil products and natural gas	-26.8	-8.5	-7.5	-42.8
Total downside risk	*-63.6*	*-13.0*	*-11.8*	*-88.3*
Steel products	9.7	4.3	0.3	14.2
Total upside risk	*-53.9*	*-8.7*	*-11.5*	*-74.1*
Total net	**-33.2**	**-26.8**	**-14.2**	**-74.1**

231. Source: WTW and UniAndes analysis

Of the downside risk identified in chapter 3 (total $88 billion), external transition risk in primarily export sectors is mostly borne by firms ($63.6 billion or 72%), with the rest being borne by national government ($13 billion or 15%) and local governments ($11.8 billion or 13%). We calculated these risk allocations first by asset, then by firm and then, by sector, after understanding how the primary instruments of explicit risk allocation allocate cash flows in each scenario. Table 31 shows how these are split between real economy sectors.

In addition, for sectors where external transition risk impacts Colombian domestic prices, Colombian consumers will also likely bear a share of risk (both downside and upside), though historically, the Colombian government has been active in smoothing the impacts of some price changes (for example, energy prices) on consumers. This means that the amount of transition risk gains and losses that accrues to consumers is a policy choice. We explore this issue in more detail in section 5.4, where we consider the ability of governments to raise additional funds via taxes on consumers.

4.2.2 Firms and their investors

Climate transition risk is initially borne by productive assets and their owners, firms in the real economy. For those firms, external climate transition risk crystallises through an impact on revenues (selling price, volume, or both) and/or costs. In any typical business environment, as firms reduce production, they automatically reduce certain "variable" costs, including much energy consumption. In this way, firms transfer a meaningful proportion of volume risk to their supply chains[232]. Certain other costs, including some labour costs, maintenance, and growth capex will vary less with production or will not be correlated with production at all. The passing of climate transition risk onto workers and the supply chain will therefore happen partially automatically and partially will be the result of strategic decisions made by management.

Using model outputs about the impact of external climate transition risk on production, our analysis of the labour market (see section 4.3.2), and information from our data providers, we assessed the amount of risk passed through to the supply chain at **$35.5 billion**[234]. Of this, **$1.9 billion** relates to direct labour costs and the rest **($33.6 billion)** relates primarily to energy, infrastructure costs (port, rail, and trucking), capital equipment and maintenance. Climate transition risk to workers and the supply chain represent a share of risk that goes beyond the risks borne by investors in the real economy firms that we have studied, and which are set out below. In practice, not all of this will represent a risk to the Colombian economy, as not all supply chain costs (particularly for capital equipment) are likely to be spent with Colombian firms. However, our research into key company sustainability reports suggests that the amount spent with international firms is limited, particularly in mining sectors.

As well as labour and other supply chain costs, royalties[236] (see section 4.2.4) and most taxes (see section 4.2.3) fall as revenues and profits decline with a residual risk accruing to (equity) investors totalling **$28.1 billion**[237]. We call this shareholder exposure the climate transition value-at-risk to equity (or CTVaR).

Table 32: **Reconciliation between the risk being faced by firms and the share likely accruing to their investors**

Downside risks left with firms after government take	Size of risks
Firm share of climate transition risk	-63.6
Passed through to labour and other supply chain costs	35.5
Minimum left with investors	**-28.1**

The investor share of **$28.1 billion** is then split according to according to the assets that particular firms have in their portfolio and the sectors that they operate in. The firms in Colombia that face external transition risk also have a range of ownership structures, including 1) majority publicly owned firms (at either national or local level), such as Ecopetrol; 2) privately held Colombian firms with Colombia-based shareholders, such as Paz del Rio; 3) Colombian subsidiaries of internationally-listed groups, such as Carbones del Cerrejón (owned by Glencore); 4) Internationally-listed companies, such as Frontera Energy; and 5) International privately-held groups, such as Drummond.

We found very little external transition risk in the sectors we analysed is currently sitting in Colombian equity markets beyond the Ecopetrol free float listed on the Bolsa Valores de Colombia (BVC)[238]. Most exposure in the sectors which face the largest downside (thermal coal and oil) is faced by companies with international shareholders.

232. Source: WTW and UniAndes analysis
233. The study has not attempted to quantify the knock-on impacts or "multiplier" effects from the impact of transition risk in studied sectors on adjacent sectors. A group of economists has developed a useful framework for what they are calling "capital stranding cascades", as set out in this South Africa-focussed paper: https://www.afd.fr/en/ressources/capital-stranding-cascades-impact-decarbonisation-productive-asset-utilisation
234. As with the revenue figures discussed in chapter 3, these figures assume that coal mines, oil fields etc. close at the point where it is economically optimum to do so (i.e. where they start to become persistently cash flow negative). In practice, we realise that closing assets is not a decision that is taken lightly and that other considerations (including the impact on employment and local economies) will be taken into account. Closing assets is therefore a choice that firms take – without doing that, the size of risk borne by firms would be substantially higher than the $63.6 billion quoted above. We explore these issues in section 4.3.6.
235. We calculated royalties and taxes at asset level and firm level and deducted those cash flows from firm free cash flows to arrive at the residual firm amounts discussed in this sub-section.
236. We call this shareholder exposure the "climate transition value-at-risk to equity" or "equity CTVaR"
237. In our assessment, BVC-listed companies, including power utilities, generally have much more exposure to domestic transition.
238. Glencore is rated Baa1 with stable outlook by Moody's Investors Service (source: https://www.moodys.com/credit-ratings/Glencore-plc-credit-rating-600018200/summary)

Table 33: **External transition risk by group of companies (investor share)**

	1. Public Colombian	2. Private Colombian	3. Part of international listed group	4. Listed abroad	5. Private international	Total
Thermal coal	-0.6	-	-2.0	-	-5.5	-8.1
Crude oil, oil products and natural gas	-13.8	-0.7	0.0	-4.3	-1.2	-20.0
Total	**-14.4**	**-0.7**	**-2.0**	**-4.3**	**-6.7**	**-28.1**

Understanding the ownership and financing structures of transition-exposed firms is important, partly because it helps us to understand how much risk might be borne by the Colombian financial sector. We would assume that Colombian-owned firms, particularly publicly owned firms, would be more likely to view Colombia as a strategic long-term market and so, shareholders (particularly where the largest shareholder is the government) might be more likely to provide additional support in the event of financial distress. By contrast firms with less strategic commitment to Colombia may have shareholders who are less willing to provide additional support and may therefore be more likely to pressure governments for additional support or "bailouts" (see sections 4.3 and 4.4).

We found that Ecopetrol has the highest absolute of external transition risk, followed by Drummond Colombia and Carbones del Cerrejón. However, Ecopetrol and Cerrejón may be better placed than Drummond to weather this transition risk. In the case of Cerrejón, this is due to its internationally diversified, investment grade shareholders[239] . For Ecopetrol, other reasons why it appears relatively resilient even to a high absolute amount of transition risk include the company's additional diversification beyond oil and gas[240] .

We found significant variation in firm CTVaRs not only between, but within the coal, oil, and gas sectors. Firms, such as Frontera Energy and GeoPark, with a higher share of future production expected to come from new assets face higher transition risk, because of the risk that they are unable to recover future capital expenditure because of lower volumes and/or prices in a WB2C scenario. By contrast, firms with greater exposure to natural gas production than to oil production, such as Canacol Energy (-20%), face lower downside risk than those more exposed to oil production.

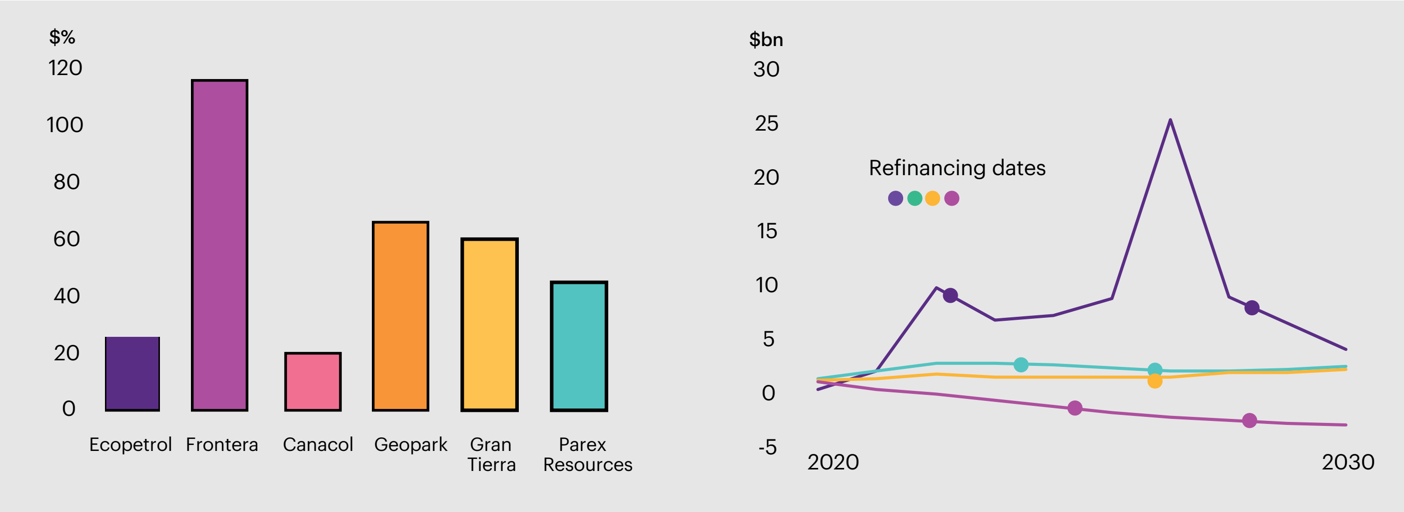
More highly leveraged firms also have more limited flexibility to deal with unpriced risks that they have limited control over such as external transition risk and physical climate risk. For all thermal coal mining companies except Cerrejón and Drummond, our analysis showed the quantum of external transition risk at close to or higher than the company's current net assets. If they do not take strategic steps to diversify, these companies could face increasingly challenging conditions to secure financing, particularly insurance[241], although the fact that the companies do not (currently) have external debt provides will provide a cushion.

Table 34: **External transition risk by major companies (investor share plus "variable cost" risk)**

	VAR	VAR (as % of BAU value)
1. Ecopetrol	13.2	-20%
2. Drummond	4.0	-81%
3. Cerrejón	2.0	-70%
4. GeoPark Energy	1.0	-70%
5. Frontera Energy	0.8	-95%
Top 5 firms	33.0	
Other firms	30.6	
Total downside firm exposures	**63.6**	

239. Ecopetrol acquired the Colombian government's stake in electricity transmission company Grupo ISA in 2021. Source: https://www.reuters.com/article/us-ecopetrol-colombia-isa-idUSKBN2FD024
240. Insure Our Future is one of a several NGOs encouraging financial institutions to pull insurance out of fossil fuel sectors : https://insureourfuture.co/wp-content/uploads/2021/11/2021-Insure-Our-Future-Scorecard.pdf
241. The large Colombian independent oil and gas companies are all rated by Fitch. Frontera at B stable (https://www.fitchratings.com/entity/frontera-energy-corporation-87107376#ratings), GeoPark at B+ stable (https://www.fitchratings.com/entity/geopark-limited-89958461#ratings) and Gran Tierra at B stable (https://www.fitchratings.com/entity/gran-tierra-energy-inc-96765130)

Figure 25: **Equity CTVaRs and credit risk for companies across companies in oil and gas value chains. Left: Oil and Gas Company VaRs. Right: Oil and gas company WB2C net debt / EBITDA.**



By contrast, Frontera Energy, Geopark and Gran Tierra, have highly leveraged capital structures with low sub-investment grade credit ratings[242]. As we show in the figure above, those producers also appear to have significant refinancing risk in the second half of the 2020s, meaning they would be at greater risk of financial distress in the event of a sharp pricing in of climate risks into financial markets[243].

Colombian firms in transition-exposed sectors have tended to raise cheaper debt in markets outside of Colombia, meaning that Colombian financial sector is likely to have limited exposure through bonds[244] .

By contrast, Colombian financial institutions could earn upside through ownership of assets in growth sectors or by lending to growing or transforming sectors, such as copper, hydrogen, biofuels, and core industrial sectors, as highlighted in chapter 5.

4.2.3 National government and consumers

As some of the largest companies and sources of exports in the country, firms in Colombia's transition-exposed sectors have historically contributed a significant share of revenues to Colombia's national budget. As such, where those firms face downside or upside transition risk from the global transition, we calculated consequent downside or upside risk in related national government revenues. At the same time, government has also historically acted to protect Colombian consumers (or groups of consumers) against large (and sharp) changes in domestic prices driven by changes in international markets. External transition risk will also affect the value of this support.

We estimate that in 2020, taxes relating to transition-exposed sectors represented around 9% of total central government revenues, with a further 4% from Ecopetrol's dividends[245]. In practice, the Colombian central government's revenue dependence on transition-exposed sectors will be higher than the amount stated here, given the taxes that will be paid by all supply chain firms (see section 4.2.2.) to the firms assessed in this study plus labour taxes relating to the people employed by these firms and supply chain firms. Having said this, Colombia's fiscal dependence on transition-exposed sectors is smaller than its trade balance dependence on exports from those sectors.

However, not all central government revenues from transition-exposed sectors will be impacted by external transition risk.

242. Frontera refinanced its 2023 maturity bonds in 2022, issuing a further $400 million, maturity in 2028 to fund a tender offer for the 2023 bonds. GeoPark's principal debt issuances mature in 2024 and 2027. Both could therefore face refinancing challenges unless they are able to diversify before a global transition accelerates
243. The SFC publishes data for Colombian financial institution portfolios on the level of each institution, but with portfolio information presented by asset class. Source: https://www.superfinanciera.gov.co/inicio/informes-y-cifras/cifras-10084734
244. According to the Marco Fiscal de Mediano Plazo 2021 (https://www.minhacienda.gov.co/webcenter/ShowProperty?nodeId=%2FConexionContent%2FWCC_CLUSTER-165808%2F%2FidcPrimaryFile&revision=latestreleased), total central government income was 152,568 thousand million pesos. The document quotes an Ecopetrol dividend of 6,549 thousand million pesos (4% of total income). Total taxes calculated WTW / UniAndes models from relevant sectors totalled 13,302 thousand million pesos (9%)
245. Source: WTW and UniAndes summary of data from MIT OEC

Table 35: **Historic trade balance in goods ($bn)**[246]

	2016	2017	2018	2019	2020
Exports	15.9	21.4	25.1	22.3	13.9
Imports	4.1	3.8	3.6	4.0	2.3
Trade balance (transition-exposed sectors)	**11.8**	**17.6**	**21.5**	**18.3**	**11.6**
Other exports and import	-23.7	-24.9	-28.2	-29.4	-21.6
Trade balance (all goods)	**-11.9**	**-7.3**	**-6.7**	**-11.1**	**-10.0**

Table 36: **External transition risk and the national public finances (2020, $bn)**[247]

	2020 revenue	Share of central government revenue	Share of GDP	Affected by external transition risk?
Corporate income tax	2.3	6.5%	1.1%	Yes
Value added tax	0.3	0.7%	0.1%	**Yes**
National tax on gasoline and diesel	0.5	1.2%	0.2%	No – because external transition risk does not impact domestic liquid fuel demand[248]
Diesel surcharge (national government share)	0.1	0.2%	0.0%	As above
Carbon tax	0.1	0.4%	0.0%	As above – because the carbon tax is levied on domestic fuel producers
Ecopetrol dividend	1.6	4.2%	0.7%	Yes
Total	**4.9**	**13.2%**	**2.2%**	

Set against these revenues are a series of costs, principally relating to energy price subsidies, but also including investment incentives. In 2020, energy price subsidies were mostly concentrated on the retail electricity and gas prices, reaching $0.6 billion[249] (or 12% of total revenues from transition-affected sectors). The annual level of subsidy provided from the public budget for consumer electricity and gas prices is difficult to predict, because it effectively acts as a top-up to a cross-subsidy mechanism (the FSSRI) which has historically had mixed effectiveness. This is because of the small number of households in the tariff categories who fund the cross-subsidy as well inefficient targeting, which has results in subsidies being provided not only to those with limited ability to pay, but also to many with high ability to pay who now live in historically poorer areas[250/251] .

246. Revenue figures for carbon tax, Ecopetrol dividend taken directly from the Marco Fiscal de Mediano Plazo 2021, other figures as per WTW and UniAndes calculations
247. This is a slight oversimplification because liquid fuel demand is partially elastic
248. The Marco Fiscal de Mediano Plazo 2021 (pg 134) quotes the change in the balance for energy and gas subsidies at COP2,426 thousand million
249. See Abdallah, C. et al. (2019) for a fuller discussion on poor subsidy targeting
250. Some risk actually sits with the distribution companies, because of timing differences between changes in wholesale costs and regulated tariffs.
251. In the Marco Fiscal de Mediano Plazo 2021 (pg 150), the MHCP projected an increase in the FEPC of COP5747 thousand million ($1.4 billion) in 2021. In the next year's document, it showed that while the actual increase for 2021 was only COP3,645 thousand million ($900 million), the projection for 2022 was COP14,218 thousand million ($3.5 billion)

In 2021, government acted via the Fondo de Estabilización de Precios de los Combustibiles (FEPC) to protect consumers of liquid fuel against rising international prices, to the tune of $900 million, and projected to provide a further $3.5 billion in support in 2022[252]. While the FEPC is designed as a price stabilisation mechanism, with deficits rising in times of higher prices and unwinding at times of lower prices, the cumulative FEPC deficit has risen steadily over the last decade, implying that it has partly functioned like a subsidy to all consumers of liquid fuels. This implies that the national government has tended to bear more of risk of higher prices than it shares in periods of lower prices. It is less clear how the mechanism will work in future, following planned actions to settle the deficit[253]. However, any stabilisation mechanism that puts less strain on Ecopetrol's balance sheet could put more risk on consumers, unless additional revenues can be raised[254] or government is willing to take on more debt.

We considered national government's explicit exposure to external transition risk in two tranches: 1) corporate income tax and value added tax in thermal coal, metallurgical coal and coke (totalling **$4.5 billion** of downside risk); and 2) all revenues and costs relating to oil and gas (totalling **$7.5 billion**).

Table 37 shows our calculation of the cumulative different in fiscal revenue between transition scenarios, by sector and by decade. Non-hydrocarbon downside is weighted to the short term because of the thermal coal sector's relatively early transition, while upsides relating to steel are more likely to be weighted to the longer term. This implies that upsides relating to existing industries like steel, regardless of their size, are unlikely to occur early enough to offset the downsides.

Table 37: **National government non-hydrocarbon VAR by period (NPV, $bn)**

	2020s	2030s	2040s	Total
Thermal coal	-2.4	-1.5	-0.5	-4.4
Metallurgical coal and coke	-0.0	-0.0	-0.1	-0.1
Non-hydrocarbon downside	*-2.4*	*-1.5*	*-0.6*	*-4.5*
Steel	1.4	1.9	1.1	4.4
Non-hydrocarbon upside	*1.4*	*1.9*	*1.1*	*4.4*
Total	**-1.0**	**0.4**	**0.5**	**-0.1**

252. The FEPC deficit has increased sharply ((https://www.reuters.com/world/americas/colombia-fuel-subsidy-deficit-projected-more-than-double-88-bln-2022-04-25/)) over the last two years, but a proposed plan set out in June could help resolve the problem in the short run (https://www.ecopetrol.com.co/wps/portal/Home/en/news/detail/Noticias-2021/plan-cover-fuel-price-stabilization-fund)
253. One additional source of revenue that could be used to fund a fuel stabilisation mechanism would be the additional tax on oil, coal and gold exports proposed in the tax reform presented to Congress in August 2022 (source: https://assets.ey.com/content/dam/ey-sites/ey-com/es_co/topics/tax/ey-tax-alert-colombian-tax-reform-bill.pdf?download) although it is less clear that this would be the most productive way to spend such revenues, which we argue could also be used to provide transition support to workers, communities, local government and small firms with limited risk bearing capacity (see chapter 5)
254 That is the say, the extent to which subsidies or stabilisation mechanisms mean that the full impact of price changes are not felt by consumers.

The oil and gas complex of revenues and costs is more complicated to forecast, because of two items which are partially affected by political considerations. First, the estimation of the share of risk borne by government in relation to domestic electricity, gas, and liquid fuel price changes[255]. Second, the quantum of annual dividends paid by Ecopetrol has not historically followed a predictable pattern in a way that is typical of listed companies (for example, to pay out a certain percentage of after-tax free cash flow).

For the fiscal revenues and costs, we assume that where liquid fuel and natural gas prices are lower in the WB2C scenario than in the BAU scenario, consumers would get access to a share of the benefit for liquid fuels, while we assume that the benefit of lower gas prices would accrue first to the central government budget, in order to reduce the subsidy, with the residual falling to consumers[256]. In relation to Ecopetrol, rather than attempting to forecast dividend payments, we have assessed the implications of the external transition for the company's free cash flows, in a same way as a financial investor might consider the change in valuation of an equity investment. Table 35 shows the results of that analysis, with fiscal flows calculated from the results of our sectoral economic modelling, incorporating our understanding of current fiscal regimes. The total net present value of the risk relating to fiscal revenues amounts to **$7.5 billion**[257].

We understand that, in practice, government officials forecasting fiscal revenues may be likely to place less weight on forecasts beyond a ten-year horizon (the period of "medium-term" fiscal planning) and may be less likely to use net present value figures relating to fiscal revenues in government planning. Figures 26, 27 and 28 below show the time series of projected government revenues from all sectors, in BAU and WB2C scenarios.

Table 38: **National government oil and gas cashflows by period (nominal, $bn)**

	BAU			WB2C		
	2020s	2030s	2040s	2020s	2030s	2040s
Corporate income tax	30.2	22.8	18.5	25.0	14.7	11.7
Value added tax	3.7	5.5	8.3	3.2	3.9	4.3
Carbon tax	2.6	3.4	4.0	2.6	3.4	4.0
Total producer-related revenues	*36.5*	*31.7*	*30.8*	*30.8*	*22.0*	*20.0*
Total consumer-related revenues	*7.0*	*8.9*	*9.7*	*7.7*	*7.9*	*7.5*
Total fiscal revenues	*43.5*	*40.6*	*40.5*	*38.5*	*29.9*	*27.5*
Ecopetrol oil and gas free cash flow	26.1	18.0	3.7	19.1	10.5	-3.5
Total government value	**69.6**	**58.6**	**44.2**	**57.6**	**40.4**	**24.0**

255. In practice, if additional revenues and/or government debt is used to fund future deficits, consumers would bear a higher share of upside risk in the event of lower prices than described above.
256. We present Ecopetrol value here as Ecopetrol dividends have been an important part of government revenues, but we consider Ecopetrol primarily as a firm (see section 4.2.2) rather than just an arm of government, per se.
257. Source: WTW and UniAndes analysis.

Figure 26: **Colombia national fiscal revenue (transition-exposed sectors, BAU)**[258]

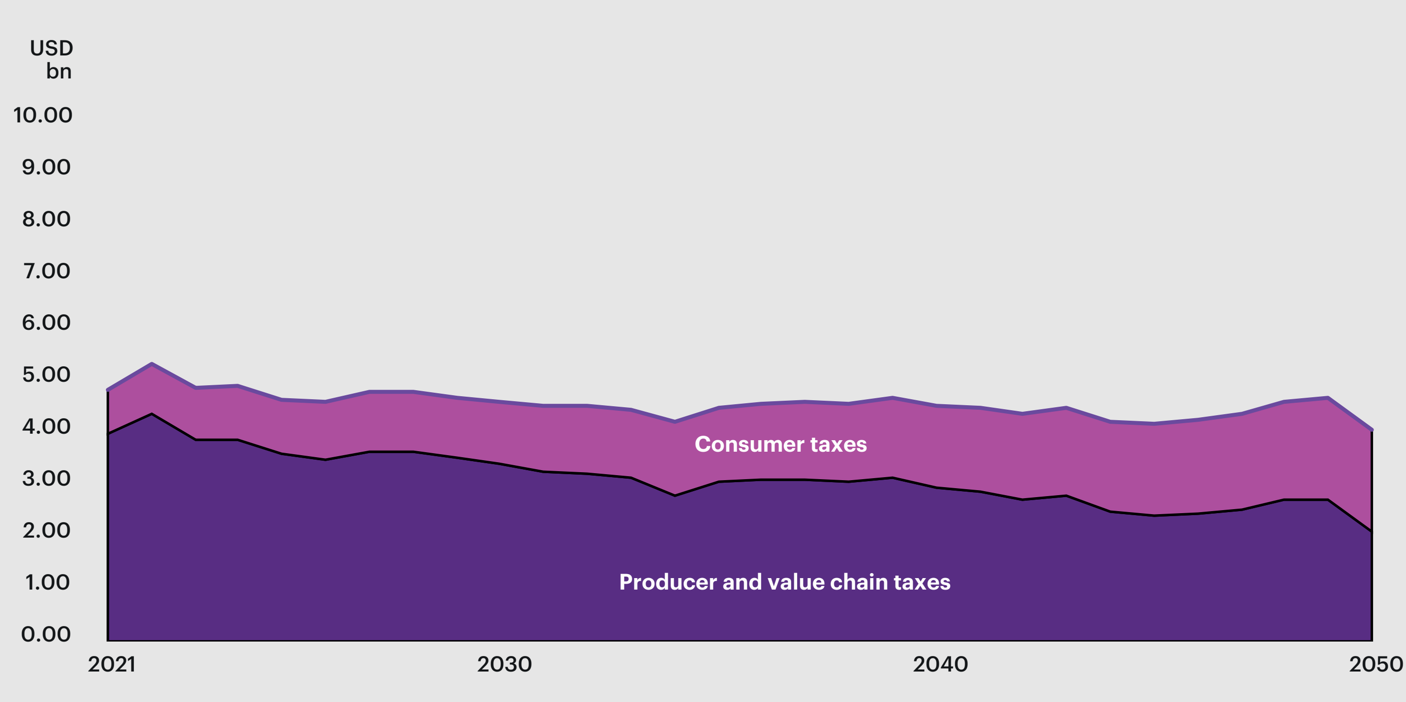
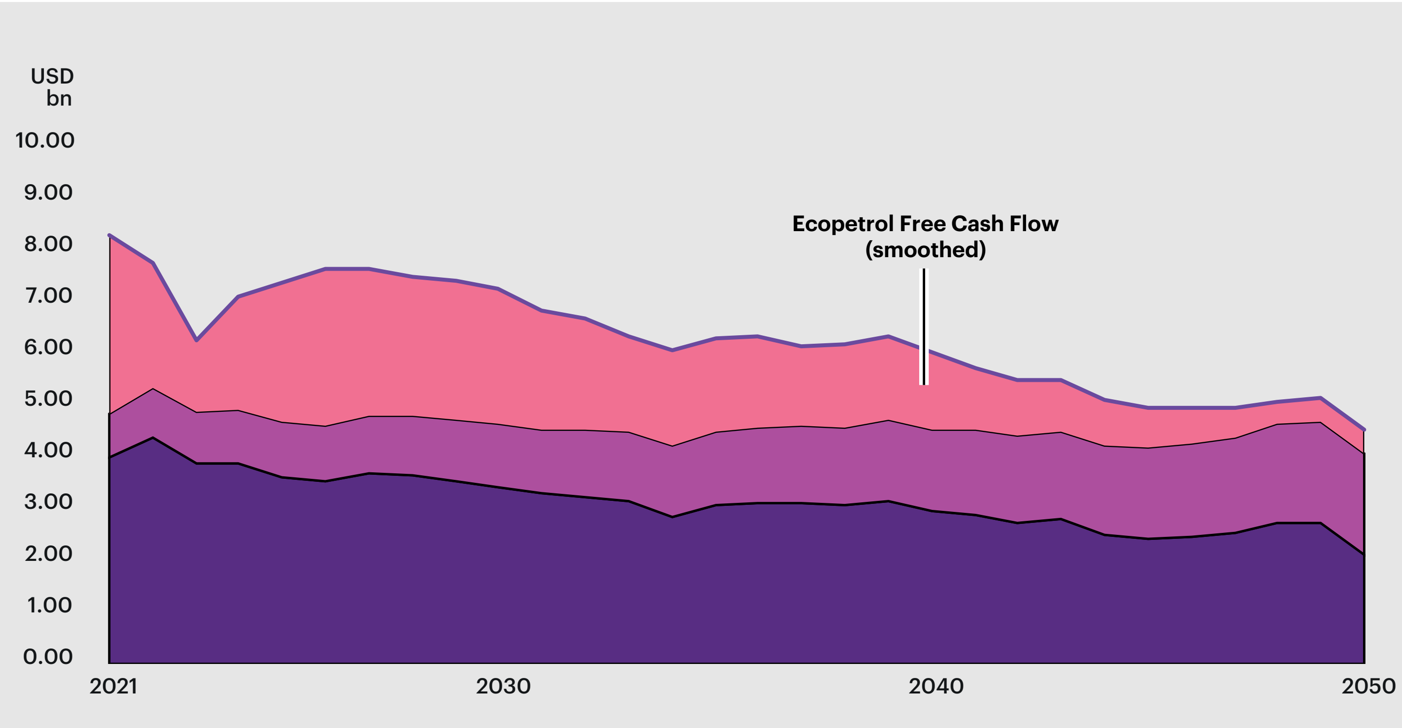
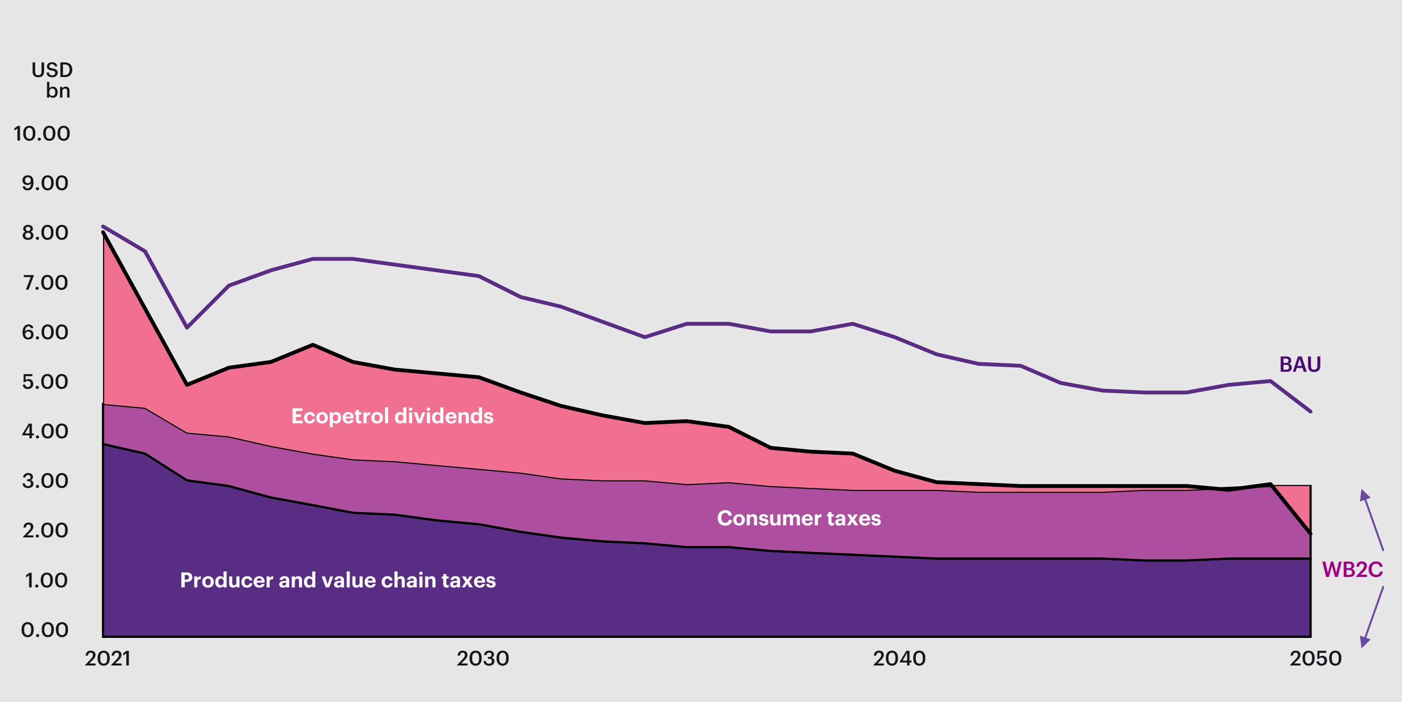


Figure 27: **Colombia national fiscal revenue plus Ecopetrol (transition-exposed sectors, BAU)**[259]



258. Source: WTW and UniAndes analysis. NB Ecopetrol figures reflect only fossil fuel businesses.
259. According to https://www.banrep.gov.co/docum/ftp/borra174.pdf, local public deficits increased "notoriously" in the 1990s, probably reflecting a combination of low productivity spending and some corruption. The combined fiscal deficits of provincial and local governments increased from low digit hundreds of billions of pesos in the first half of the 1990s to close to 2 trillion pesos in 1999.

Figure 28: **Colombia national fiscal revenue (transition-exposed sectors, WB2C vs. BAU)**



The implication of the risks highlighted above could, when combined with the external imbalances set out in chapter 3, prove serious for the sustainability of Colombia's public finances, potentially resulting in reduced public investment and/or higher public debt. Furthermore, in addition to the risks highlighted above, we would expect additional demands for public resources from other parties, including local governments, some of which face more severe external transition risk, because of their economic reliance on transition-exposed sectors and already limited financial flexibility. These issues are explored in greater detail in sections 4.3, 4.4 and 4.5.

4.2.4 Local government

As with national government, local governments (at both departamento and municipio level) in Colombia face exposure to external transition risk via an impact on revenues. Some also have investments in companies that operate in transition-exposed sectors (such as power generation company EPM, owned by the City of Medellin), but our analysis suggested that power generation and distribution companies are exposed to a greater degree to the domestic transition than the global transition.

Local governments in Colombia have historically had limited revenue-raising powers[260] and limited capacity to take on debt[261], meaning that their ability to cover their costs, provide local services and make local investments has largely been dependent on fiscal transfers from central government (the Sistema General de Participaciones or "SGP")[262] and royalties collected by national agencies and then redistributed to local governments (through the Sistema General de Regalias or "SGR")[263]. In 2020, local governments in Colombia earned $19 billion[264] in revenue, of which 54% related to transfers and royalties. The largest amounts of oil and gas royalties were generated in Meta and Cesar departments.

On the distribution side, despite SGR mechanisms for redistributing royalties around the country, producing departments remain some of the most dependent on royalties as a share of annual revenues. In recent years, Arauca and Meta were most dependent on those revenues.

260. Per https://economic-research.bnpparibas.com/html/en-US/Colombia-Public-Finances-cause-concern-3/18/2022,45126, Colombia imposed constraints in the late 1990s, severely constraining the ability of local governments to raise debt without national government consent. Although in recent years, several large local governments have obtained approval to pledge future tax revenues as security for infrastructure financing
261. The SGP is a general transfer mechanism which, according to WTW and UniAndes analysis of historic data, contribute between 40% to nearly 70% of departamento annual revenues. The total amount transferred annually under the SGP was originally set at just under COP11 billion in 2001 and, by law (Article 2 of Law 715 of 2001: https://siteal.iiep.unesco.org/sites/default/files/sit_accion_files/co_0374_0.pdf) and is expected to rise in line with the growth of government revenues. However, it cannot fall below the starting figure in year.
262. The definitive guide to understanding how royalties are distributed following the 2020 reform is in this document from the DNP (https://colaboracion.dnp.gov.co/CDT/DNP/SIG/M-CA-04%20Manual%20de%20distribuci%C3%B3n%20del%20SGR%20entre%20fondos%20y%20beneficiarios.Pu.pdf (Accessed 26 August 2022). In simple terms, revenues are collected redistributed to departamentos and municipos according to legislative formulas. Roughly, direct allocations to regions where minerals are extracted account for around 25% of the total. Of the residual, specific amounts are allocated for regional investment (34% of the total), local investment (15% of the total), with individual allocations being determined according to a combination of poverty and population factors. Additional amounts are held in central funds (for example, for science and technology investments) where local governments have to bid for a share. A further amount is, in most years, saved in a buffer fund, to be drawn down on in years where royalty revenues are lower than expected (the Fondo de Ahorro y Estabilización or FAE).
263. The Marco Fiscal de Mediano Plazo 2021 (pg 162) quotes total income for local and regional governments at COP76,332 thousand million, of which COP5,948 thousand million related to regalias and COP35,102 thousand million related to transfers.
264. Source: WTW and UniAndes analysis

Figure 29: **Historic reliance on SGR revenues by department**[266]

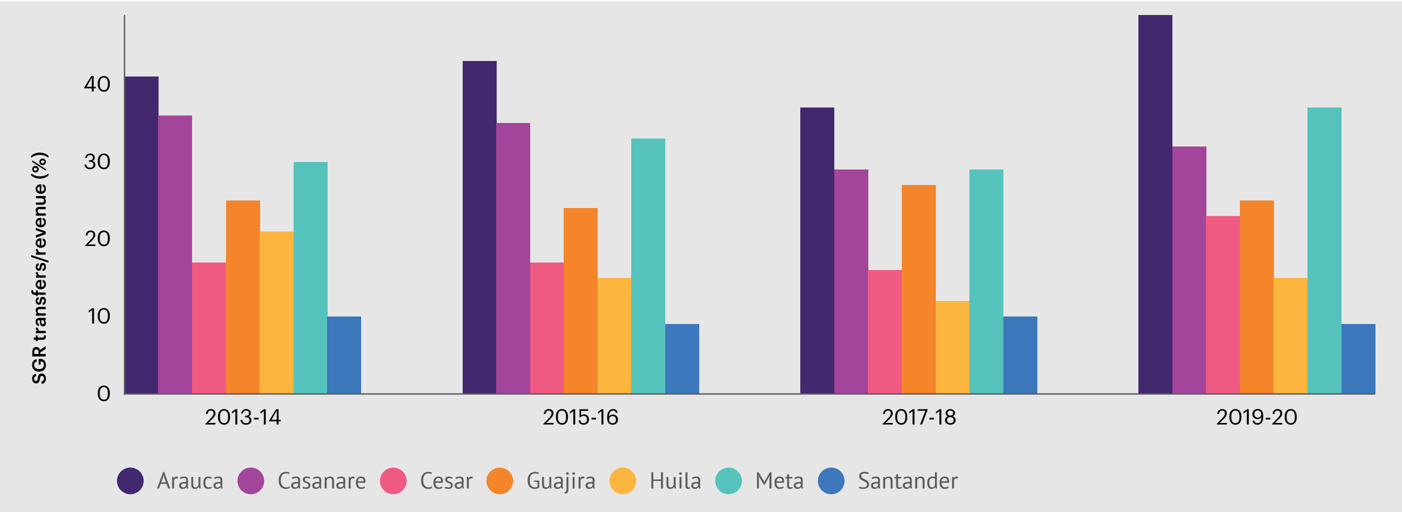
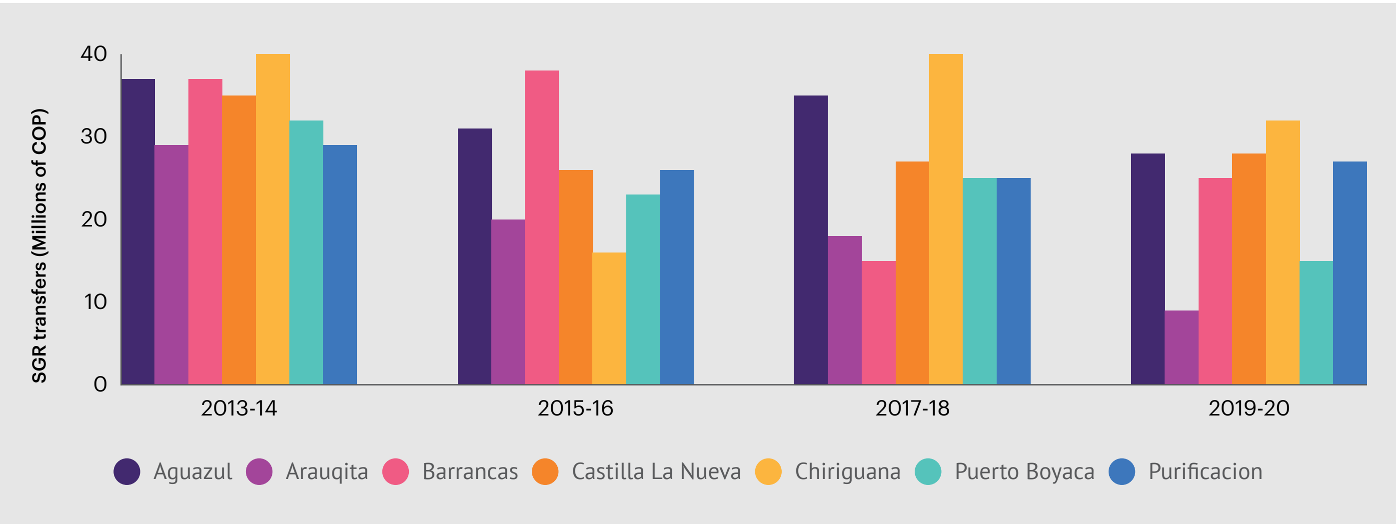


Figure 30: **Historic reliance on SGR revenues by municipality (selection)**[267]



We observed a higher level of historic dependence on SGR revenues at the municipality level, with Purificación province in Tolima reliant for over 40% of total revenues across 2019-2020.

More broadly, other than the amount of mineral and hydrocarbon production, the level of reliance on transfers and royalties, will depend on the size of the local tax base, relative that government's budget. Some locally levied taxes, such as the industry and commerce tax (ICA)[268] and property taxes, affect all economic sectors, including transition-exposed sectors. In locations that are economically dependent on a particular business or producing asset, this can result in significant dependency on ICA revenues, for example, in Barrancabermeja.

Other taxes are charged direct to consumers, such as the gasoline and diesel fuel surcharges[269]. These taxes are more important in the largest cities, which have the highest fuel consumption.

Across royalties, ICA, and fuel surcharges, we estimate that around 11% total local government revenues were dependent on transition-exposed sectors in 2020. However, as with national government, our analysis suggested that not all these revenue sources would be exposed to external transition risk.

265. Source: WTW and UniAndes analysis
266. Source: WTW and UniAndes analysis
267. ICA is a revenue tax created under Law 14 of 1983 (https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=267#:~:text=%2D%20A%20partir%20del%201%20de%20enero%20de%201983%2C%20las%20tarifas,destinaci%C3%B3n%20econ%C3%B3mica%20de%20cada%20predio.). Municipalities have the rights to set the rate of this tax within certain bounds set for major types of activities (for example, for industrial activities, rates can be set at between 0.2-0.7% of revenues). In practice, this makes it difficult to forecast without a decree of approximation.
268. Surcharges on gasoline and diesel have been in place and paid by the Colombian consumer since the late 1990s (Laws 488 from 1998 and 788 from 2002). In 2021, Congress passed Law 2093 which changed the tax calculation from an amount calculated in relation to a reference price specified monthly by the Ministry of Mines and Energy to a fixed amount per gallon sold. Source: https://dapre.presidencia.gov.co/normativa/normativa/LEY%202093%20DEL%2029%20DE%20JUNIO%20DE%202021.pdf
269. Source: WTW and UniAndes analysis

Table 39: **External transition risk and the local public finances – 2020 ($bn)**[270]

	2020 revenue	Share of local government revenue	Affected by external transition risk?
Royalties – coal, oil, gas, and copper	1.5	7.8%	Yes
ICA – relevant sectors			Yes
Gasoline surcharge	0.6	2.9%	No
Diesel surcharge (local government share)	0.1	0.4%	No
Total	**2.2**	**11.1%**	

External transition risk will impact the revenues and production of assets in transition affected sectors, changing the level of royalties and ICA collected. The impact of sharply lower-than-expected royalties on royalty income for municipalities may only be partially smoothed by the stabilisation mechanisms in the SGR system (FAE and FONPET). However, since those mechanisms are designed to protect local governments against cyclical volatility, rather than structural change, the mechanisms would be insufficient to protect local governments against long-run declines in royalty revenues.

Overall, we assessed total local government external transition risk at **$11.8 billion**, the majority of the risk arises from the decline in royalties from the decline in coal and oil production.

Within this consolidated picture, our analysis showed the levels of exposure varied significantly between department, and municipalities.

While there are some mechanisms within the SGR system to redistribute royalties from producing regions to non-producing regions, the fact that 25% of total royalties collected are distributed as "direct allocation" back to producing regions means that producing regions retain a greater share of value and transition risk exposure than non-producing regions.

Table 40: **Local government revenues by scenario from transition-exposed sectors (nominal, $bn)**

	BAU			WB2C		
	2020s	2030s	2040s	2020s	2030s	2040s
Royalties	18.5	11.4	26.9	14.5	5.5	3.7
ICA	1.9	2.6	3.8	1.6	1.6	1.6
Total	**20.4**	**14.0**	**30.4**	**16.1**	**7.1**	**5.3**

270. Source: WTW and UniAndes analysis

Municipality share of royalty income is likely to be even more volatile than the share going to departments, as declining production from particular oil and gas production sites could cause the designation of particular municipalities to shift from "producer" to "non-producer", reducing that municipality's direct allocation of royalties. Declining revenues in any given region can have a double impact, given that it will also reduce the tax base on which ICA is charged. For example, ICA has represented between 35 to 45% of revenues for Barrancabermeja municipality over the last ten years and 5% for Santander department, where Barrancabermeja is located. Our analysis showed that departments and municipalities with significant dependency on ICA generally have time to diversify their revenue bases, given that the impact of external climate transition risk is unlikely to hit until the late 2030s, compared with the decline in royalties which could happen much more quickly.

The current structure of the municipal financing system – where municipalities facing declining revenues at the same time as economic activity declines – means that it is not (at least in its current form), well suited to support local governments through a climate transition. As local governments have limited ability to take on debt, lower revenues would lead to lower levels of investment and could lead some local governments into financial distress.

4.3 Strategic behaviour and implicit risk transfer

4.3.1 Summary

Although firms (including supply chains and workers), and their investors explicitly bear 73% of external transition risk, we expect that that they would seek to transfer as much risk as possible onto other parties.

However, from our experience of analysing company transition strategies globally and review of documents published by Colombian firms and interviews with Colombian industry participants, it is clear that most firms considering "transition risk" are not yet considering external transition risk in the way described in this paper. Colombian firms engaging with climate transition risk are, instead, mostly developing strategies to reduce their GHG emissions and in so doing, hoping to reduce future costs associated with carbon taxation and carbon pricing in Colombia[273].

Through the authors' previous research and discussions with Colombian stakeholders, we have identified 4 principal groups of strategies for firms trying to offset or mitigate their external transition risk.

Table 41: **Potential firm transition risk mitigation strategies**

	Passes risk onto other parties?	Who is affected?
Renegotiate terms with supply chain	Yes	Workers, smaller firms in supply chain
Earn additional revenues for current products in new markets	Yes	Competing producers in alternative markets, consumers (through prices)
Shift investment towards new products / markets	No	-
Close persistently loss-making assets	Yes	Workers, local government, national government, supply chain and infrastructure

At the same time as firms develop strategies for reducing emissions and reducing transition risk, Colombian and international financial institutions are likely to start developing strategies for managing their own transition risk, which, in turn, will impact on the ability of Colombian firms to continue to access capital at reasonable rates.

Finally, we expect that the Colombian national government will take actions aimed at mitigating the country's transition risk, including the provision of support to firms facing transition downside. In doing this, the government may – deliberately or inadvertently – facilitate the transfer of risk from real economy firms to the public balance sheet.

We have not sought to quantify the impact of potential firm actions (1-4), given that these could vary widely with their level of proactivity. Sizing the amount of government support to public bodies (5,6) is more straightforward given the strong commitment of national government to public bodies as employers and deliverers of public services.

Estimating the amount of support that national government might be willing to provide to private sector actors is a more challenging task, as it will depend on subjective factors, such as the strategic importance that government ministers place on the continued operation of particular firms vs. the cost of supporting them. In total, we estimated that implicit risk transfers could transfer at least **$26 billion** to the national public balance sheet from state-owned firms and local governments.

271. Source: UniAndes and WTW analysis
272. Canacol appears typical in the Colombian context in generating a TCFD report without transition risk as a key metric in addition to carbon footprint (source: https://esg.canacolenergy.com/tcfd-index/). Ecopetrol's definition of transition risk is more comprehensive, but quantification is limited as yet (source: https://www.ecopetrol.com.co/wps/wcm/connect/f377c849-1135-49c3-abc6-d74c09e596d6/english-tcfd.pdf?MOD=AJPERES&attachment=false&id=1628049465069)
273. Source: https://www.reuters.com/article/us-colombia-mining-idUSKBN2BI35I based on BECO

Table 42: **Potential national government support for parties facing transition risk**

	Transfers risk from other parties?	Who is affected?
Support to state-owned enterprises	Yes	National government, consumers
Supporting regions at risk	Yes	Local government
Supporting firms and sectors at risk	Yes	National government, consumers

4.3.2 Firms: renegotiate terms with supply chain

Firms in the real economy tend to have a strong ongoing incentive to minimise controllable costs with the aim of maximising profits and value. However, in the face of external transition risk that results in lower sales volumes and profits, we would expect firms to seek to reduce or renegotiate some quasi-fixed costs related to labour, infrastructure costs (such as rail and port handling cost) maintenance and growth capex, in order to conserve profitability at lower production levels.

In practice, a firm's ability to reduce labour costs (or to change employee terms) while an asset is in operation and solvent will depend on technical considerations (what is the minimum number of staff required to sustain maximum production) as well as labour rights. The latter, in turn, will be influenced by the extent to which the workforce is employed on a formal or informal basis; on permanent or temporary contracts; and the level of trade union membership. For the coal mining, we reviewed the impact of the COVID-19 lockdowns of 2020, to assess the "variability" of labour costs with production.

In 2020, faced with sharp, unexpected disruption relating to the pandemic, Colombian coal production fell from 84 million tonnes in 2019 to 49 million tonnes[274]. However, exports fell by less than 10% (to 68 million tonnes), with Colombian producers drawing down on inventories rather than spending on production. Domestic consumption was almost flat, with an increase in coal used for power generation largely offsetting the decline from industrial production. Labour disputes, including a three-month strike by workers at Cerrejón, compounded the issues for producers[275]. The industry faced further disturbance in 2021 due to protests by former workers and local indigenous communities which blocked the rail line from Cerrejón to the company-owned port at Puerto Bolívar[276].

In 2020, almost all Colombian production decline came from the northern regions. For the major mining companies, the number of contracted workers fell by 43%, while the number of workers in full employment fell by only 6%, as shown in table 43.

From these results, we inferred two things with relevance to a longer-term structural transformation that would occur in a WB2C scenario. First, mining companies find it easier to reduce labour on temporary contracts than those on permanent, formal employment contracts. Second, the relatively high share of labour on permanent contracts contributes to the meaningful power of workers to resist changes to working conditions that stop short of unemployment. This level of employment tenure, combined with a total union membership in the region of more than 4,000[280], will limit the ability of firms to pass climate transition risk down to workers, while a mine is in operation. This will likely mean that coal mining workers in the north of Colombia are only likely to face climate transition risk when assets eventually close. By contrast, workers not employed by coal mining firms, but operating in the supply chain, such as coal truckers and service industries serving coal workers, are much more likely to see impacts as volumes produced fall.

Beyond the coal sector, we expect more limited impact on workers in primary sectors that face downside risk, such as coke and the oil and gas value chain. This is because, unlike in thermal coal, the impact of external climate transition risk relates primarily to changes in prices and not volumes (thermal coal faces downside to volumes and prices). Complex industrial operations, like refineries, face technical limitations, which limit the extent to which their operating patterns can be adjusted, including changes to the amount of labour input.

274. Source: https://www.argusmedia.com/en/news/2164681-colombias-cerrejon-coal-strike-ends
275. Source: https://www.argusmedia.com/en/news/2240709-colombian-coal-railway-reopens-after-threeday-blockade
276. Source: Cerrejón Sustainability Reports 2019 and 2020. (Sources: https://www.cerrejon.com/sites/default/files/2021-09/sustainability-2020.pdf and https://www.cerrejon.com/sites/default/files/2021-09/sustainability-2019.pdf)

Table 43: **Historic coal mining company employment by company**

	2019			2020		
Mining company	**Employed**	**Contractors**	**Total**	**Employed**	**Contractors**	**Total**
Carbones de Cerrejón[277]	5,896	5,166	11,062	5,201	3,319	8,520
Drummond[278]	5,137	5,440	10,577	5,039	5,535	10,574
Prodeco[279]	2,523	4,808	7,331	2,500	-	2,500
Total	**13,556**	**15,414**	**28,970**	**12,740**	**8,854**	**21,594**

4.3.3 Firms: earn additional revenues by selling product into new markets

Just as certain Colombian firms – such as coal miners in Cundinamarca, Boyacá and Norte de Santander – have supplemented their domestic earnings on an opportunistic basis by exporting excess product, so those firms typically focused on export markets may seek to sell product into domestic markets if export markets start to decline, as discussed in this paper.

As set out in chapter 3, the sectors that would be expected to face lower exports in a WB2C scenario, relative to a BAU scenario are thermal coal, metallurgical coke, and crude oil. For coke producers, this strategy would not be an option, since the only domestic consumer of coke – Paz del Rio – is now owned by a consortium including one of the leading coke producers (Coquecol)[281]. This means there would be no effective competition for Paz del Rio's demand. For crude oil producers, which in any case, face limited volume downside from a global transition, there would similarly be limited substitution of oil that would otherwise be exported for oil that would be used domestically, especially given Ecopetrol's ownership of Colombia's oil refining capacity and dominance of the crude oil production business. Only for thermal coal miners might there be an opportunity to sell some additional coal into domestic markets.

Colombian coal miners facing external transition risk might consider competing for a share of the domestic market. However, at 6.3mt in 2019, compared with total production in that year of 84.3mt, the domestic market is relatively small. Domestic power plants and larger industrial facilities (such as cement plants) may also be optimised for particular coals. Finally, coal that would otherwise be exported may not be able to compete in domestic markets, given the high costs of inland infrastructure. As illustrated in table 44, for a mine like El Descanso in Cesar, the trucking cost of transporting coal to power plants and industrial facilities would strongly hinder its competitiveness.

The only other option for coal miners to sell excess supply into domestic markets would be to expand coal-fired generation capacity. However, this is also unlikely because new coal-fired power plants would be much more expensive than new wind and solar generation capacity[283] and because the companies would be very unlikely to be able to secure financing for new capacity[284].

277. Source: Drummond Ltd Sustainability Reports 2019 and 2020. (Sources: https://issuu.com/drummondltd/docs/is_drummond_2020_202111223_engdigital?fr=sMmJmMDM5NDk1ODc and https://issuu.com/drummondltd/docs/2019-sustainability_report_-_en?fr=sMGU4ZjM5NDk1ODc)
278. Prodeco stopped publishing Sustainability Reports in 2018, however we take the 2018 figures (https://www.grupoprodeco.com.co/.rest/api/v1/documents/4abc363f8290a89de3cb0c2545cc54c4/Sustainability%20Report%202018%20English.pdf) to represent 2019 as there was limited change in Prodeco operations between 2018 and 2019. We understand that when Prodeco stopped operations in March 2020, it continued to make payments to those formally employed, but stopped payments to contractors immediately (source: https://www.argusmedia.com/en/news/2120730-prodeco-seeks-longer-suspension-of-colombia-coal-mining).
279. Source: https://www.argusmedia.com/(F(6sN0TMA04To-6MEDIvkvX_aRYT9wgtylrWRsXhdmVNIzlJ78toJhUUu39m39WcU8uOg1ndBMlnV37iCJflb_KJ_gQuLMz0XS739BP7FvlbwsAMJHhHwQOlugvS-1MwsMVFBFK1XmteNON_-5WjdSWIGetanSKsub7qe_ZqdZt7SPDwOF0))/pages/NewsBody.aspx?frame=yes&id=2131442&menu=yes
280. Source: https://forbes.co/2022/01/18/negocios/este-es-el-plan-de-trinity-capital-tras-la-compra-de-acerias-paz-del-rio/
281. Trucking cost estimates were obtained from a non-public report from mining consultant John T Boyd

Table 44: **Potential El Descanso transport costs ($/t): current and potential future markets**

Destination	Distance	Department	Transport and handling cost [282]	Mining and royalty cost	Total cost
Puerto Drummond (current)	221 (by rail)	Magdalena	8.4	40.7	49.1
Gecelca	531	Córdoba	52.6	40.7	93.3
Guajira	334	La Guajira	33.1	40.7	73.8
Paipa	654	Boyacá	64.8	40.7	105.5
Zipa	738	Boyacá	73.1	40.7	113.8
Tasajero	443	Norte de Santander	43.9	40.7	84.6

While the domestic market is unlikely to "soak up" much, if any, excess coal supply, coal mining companies may hope to carve out a protected niche in the export market. This could include a "stickier" segment of demand that prioritises the quality of Colombian coal or even an attempt to create a "carbon neutral coal" product, similar to the very small market for "carbon neutral crude oil"[285] and "carbon neutral LNG"[286]. In theory, if Colombian coal miners could buy (or create) carbon offsets in the Colombian voluntary carbon market, then they might be able to preserve demand for Colombian coal by selling to buyers in markets with carbon prices higher than the cost of the offset. However, we remain cautious about the extent to which "carbon neutral coal" or "green coal" could be an effective risk mitigation strategy for Colombian firms. On the one hand, global capital markets and commodity markets have shown signs of incorporating more qualitative factors beyond economics. These range from so-called ESG factors to more targeted measures (for example, RMI's attempts to introduce a standard to grade LNG according to its level of methane leakage)[287]. In addition, with the ever-increasing materiality of ESG analysis and influence of certifications such as those set out by the Science-Based Targets Initiative, we would expect investors and insurers increasing to charge a premium for companies seeking to use offsets, rather than genuine emissions reductions, as a means of reducing their carbon footprints[288].

Companies that produce coke may also have options to diversify their customer base away from the steel sector, by selling their products to other growing industries. One option might be a nascent metal refining/smelting sector which Colombia is considering developing to maximise the capture of value add from copper and nickel mining[289]. However, while coke is there must remain uncertainty about the potential longevity of such a strategy, metal refiners will also face pressure from investors to decarbonise their supply chain away from emissions-intensive materials such as coke.

282. Source: https://www.irena.org/newsroom/pressreleases/2021/Jun/Majority-of-New-Renewables-Undercut-Cheapest-Fossil-Fuel-on-Cost
283. Source: https://unfccc.int/news/end-of-coal-in-sight-at-cop26
284. Source: https://www.reuters.com/business/sustainable-business/clean-crude-oil-firms-use-offsets-claim-green-barrels-2021-04-16/
285. There has been much rebuttal about the science, market structure and viability of fossil fuel production offsets in a well-below two degrees scenarios, including: https://www.csis.org/analysis/credibility-gap-carbon-neutral-lng#:~:text=The%20appeal%20of%20carbon%2Dneutral,programs%20to%20new%20wind%20farms.
286. Source : https://miq.org/
287. Source : https://sciencebasedtargets.org/faqs#:~:text=The%20SBTi%20requires%20that%20companies,)%20or%20net%2Dzero%20target.
288. Here, coke making by-products are used in the production of electrodes (see chapter 3)
289. Source: https://www.reuters.com/article/us-ecopetrol-colombia-isa-idUSKBN2FD024

4.3.4 Firms: diversification into other products

Companies invested in Colombian extractive industries are already starting to work to diversify their portfolios. They can do this by acquiring companies or investing in assets that either have climate transition upside or at the very least are resilient to the transition. Examples of this include the diversification of previously oil-focused firms to invest in gas, Ecopetrol's acquisition of electricity transmission company ISA[290], Drummond's explorations into coal-bed methane[291] and coal and coking company Carbomax's explorations into copper[292]. There are an increasing number of pilots around the world to convert oil refineries to produce low-carbon fuels (or e-fuels) using green hydrogen. Where they have access to sufficient capital, other coal mining companies may also have opportunities to invest in other mining activities (such as copper).

Diversification in this sense is a means of offsetting, rather than mitigating, transition risk in existing portfolios. However, at the current moment, we see a strong chance that, rather than accelerating diversification, Colombian companies may actually double down on new fossil fuel supply or infrastructure assets, spurred on by price spikes on global markets that have intensified since the beginning of the war in Ukraine. If companies pursue investments with long-term payback periods in transition exposed sectors (whether external or domestic transition risk), they risk increasing, rather than decreasing their climate transition risk exposure.

Accelerating these investments could help mitigate external transition risk, particularly where companies divert new capital investment budgets into sectors that either have climate transition upside or are at the very least resilient to the transition.

4.3.5 Firms: divest transition-exposed assets

An apparently simple route for firms (and financial institutions) to mitigate climate transition risk is through divestment. This is more likely to be an option for the largest companies with diversified portfolios (such as BHP Billiton and Anglo American, who sold their stakes in Cerrejón to Glencore), than for those whose operations are very dependent on Colombia (such as Drummond).

Where divestments do happen, these may crystallise climate transition risk, if the selling price factors in the risk. However, with climate transition risk still mostly unpriced, divestments are more likely to shift exposure to climate transition risk from the original owner to a new owner, with uncertain ability to bear that risk. We are not yet aware of any specific examples of this taking place in Colombia but have noticed a broader trend for internationally diversified mining companies divesting coal assets to local players with smaller balance sheets[293].

4.3.6 Firms: close persistently loss-making assets

Another option for firms with assets facing climate transition downside is early closure. Early closure may stem the losses from a declining asset, but it will typically mean additional costs being incurred since mining companies in Colombia are not typically required by license or regulation to pre-fund closure costs[294]. The decision to close an asset early may not be taken lightly and we would expect companies to seek to negotiate with Colombian regulators and the government to try to avert such a situation (hence, sharing the climate transition risk). However, if assets are closed, it would imply a transfer of climate transition risk from firms and their shareholders onto local government (via a reduction in ICA), workers, energy providers and other providers of services to the given mine, field or industrial asset. In the context of asset closures, we would see limited risk being transferred onto national government, unless the owner was on the verge of bankruptcy[295].

From the analysis set out chapter 3, we identified the following assets currently in operation and at risk of early closure resulting from external climate transition risk. In addition, there is a chance that new assets are developed, with investment spurred by short-term price signals, which would also face early closure in a WB2C scenario, including all new export-oriented thermal coal mines and much prospective unconventional oil production.

290. Source: https://www.argusmedia.com/en/news/2034454-drummond-ordered-to-halt-cbm-gas-production
291. Carbomax was recently awarded one of the five Strategic Mining Areas for copper allocated by the Colombian government. Source: https://www.elcolombiano.com/negocios/empresas/carbomas-buscara-y-producira-cobre-en-la-guajira-norte-de-colombia-GE15660161
292. Anglo American have done this in South Africa by divesting assets in separate transactions to local players Seriti and via listing on the Johannesburg Stock Exchange https://www.angloamerican.com/media/press-releases/2018/01-03-2018
293. We understand that mining companies are required by license to fund closure costs and post-closure costs (such as those for rehabilitation and recovery of an area after the closure of an asset) but are not required to pre-fund these. We were not able to ascertain the conditions under which Glencore was able to hand back its Prodeco licenses, although we assume that the company would be liable for at least some closure costs.
294. Our understanding is that firms would only be discharged of their responsibilities to bear closure and pre-closure costs in the case of bankruptcy. In this case, in practice, the risk would effectively pass to the national balance sheet although it is not clear to the authors whether the state would be compelled to pay these costs under the Colombian constitution.
295. Closure dates for Cerrejón and El Descanso in WB2C are especially uncertain, since realized prices are close to breakeven. The forecasted WB2C closure dates for these mines are based on when these realised prices could drop below baseline cost forecasts.

Table 45: **Potential early closure of assets in WB2C scenario**

Asset	Industry	Potential closure date in WB2C
El Hatillo	Thermal coal mining	First half of 2020s
Calenturitas	Thermal coal mining	First half of 2020s
Cerrolargo Norte	Thermal coal mining	First half of 2020s
La Francia	Thermal coal mining	First half of 2020s
Caypa	Thermal coal mining	First half of 2020s
Quifa	Crude oil production	First half of 2020s
Vigia	Crude oil production	First half of 2020s
Sabanero	Crude oil production	First half of 2020s
El Descanso	Thermal coal mining	Second half of 2020s[296]
El Corozo	Thermal coal mining	Second half of 2020s
La Jagua	Thermal coal mining	Second half of 2020s
Cerrolargo Sur	Thermal coal mining	First half of 2030s
Cerrejón	Thermal coal mining	First half of 2030s[297]
Zopilote	Crude oil production	First half of 2030s
Coking plants	Metallurgical coke	Late 2030s / Early 2040s
Barrancabermeja	Oil refining	Early 2040s

To assess the quantum of risk that would be transferred to workers in net present value terms, we compiled data on worker numbers and labour costs. For worker numbers, we assumed that for large mines in La Guajira and Cesar and for Colombia's oil refineries, workers would only lose their jobs when assets close. By contrast, for oil and gas production workers, we assumed a link between production and worker numbers, due to the modular nature of oil and gas production. Similarly, for coal mining workers in the interior of the country, we also assumed that labour costs were more "variable", reflecting a lower share of workers in full employment.

Table 46 reflects the results of this analysis of the extent to which Colombian workers in selected would be impacted by a global WB2C scenario. The total labour value at risk of $1.9 billion likely represents a significant underestimate of the extent to which Colombian workers across the economy (most notably in supply chains) would be affected, starting in the coal industry in the 2020s.

296. See previous footnote.
297. See previous footnote.

Table 46: **Worker exposure to external climate transition risk (number of direct workers)**

	BAU				WB2C			
	2022	**2030**	**2040**	**2050**	**2022**	**2030**	**2040**	**2050**
Thermal coal – La Guajira and Cesar[298]	31,229	37,086	21,244	8,536	27,986	21,264	10,572	8,536
Coal – interior regions[299]	22,276	22,154	22,154	22,154	21,761	18,822	18,822	18,822
Crude oil production[300]	11,488	6,560	2,893	1,062	11,455	6,126	2,767	678
Oil refining[301]	10,094	10,094	10,094	10,094	10,094	10,094	10,094	4,454
Total	**75,087**	**75,894**	**56,385**	**41,846**	**71,296**	**56,306**	**42,255**	**32,490**

Unless alternative sources of jobs can be found in the regions where these assets close, the closure of the assets and decline in direct employment will also have an important multiplier effect – both in the decline of economic activity of the services directly supporting the assets, but through the impact of the risk borne by workers on their families and dependents and their economic activities (see section 4.6). For the coal industry in particular, heterogenous affects across regions must be considered when dealing with unemployment. By 2040, Cesar and Guajira can expect half the number of coal jobs in a WB2C scenario, in comparison to a BAU scenario. The interior regions of Boyaca, Cundinamarca and Norte de Santander, in contrast, are much better insulated from global trends, with their markets being dominated by a metallurgical coal and with thermal coal mostly sold into domestic markets. The latter business is particularly exposed to Colombian domestic transition risk, which could mean employment level declining much faster than the picture presented above, especially in the event of accelerated coal power plant closures.

4.3.7 Financial sector: ESG

As well as declining production and revenues, firms that face climate transition downside, could also, all other things being equal, expect to see an increase in their cost of capital and their creditworthiness declined. However, those same firms may also see a double impact on cost of financing as more and more firms incorporate ESG metrics into their investment decisions. For some firms, the impact of ESG metrics may be binary – for example, we see very little available finance for new coal fired power stations in the world outside of China and India. In some cases, the impact may happen suddenly – for example, as most insurance is provided only on an annual basis, changes in the insurance market, which have seen an increasing number of insurance firms stepping back from providing underwriting capacity to coal companies, can happen quickly[302]. The impact of changing conditions in global financial markets is likely to affect companies with listed securities sooner than those in private markets, given that awareness of and disclosure of ESG and climate risks have, in many cases, been promoted first by stock exchanges[303].

While ESG and climate risk issues may be related, we might expect the impact of the ESG trend to be reflected already in the actions and pricing provided by financial institutions today, whereas climate risk, by definition, relates to the as yet unpriced downside or upside.

ESG-related and climate risk mitigation actions by financial institutions can potentially compound the otherwise declining financial positions of real economy firms, potentially inadvertently pushing risk onto workers, creditors, and the national government, if those firms tip into bankruptcy.

298. We reached a starting estimate of coal mining workers in Boyacá, Cundinamarca and Norte de Santander using data from the Censo Minero 2011 (https://repository.usta.edu.co/bitstream/handle/11634/2923/2015lauragonzalez19.pdf?sequence=59&isAllowed=y) and cross referenced with historic production data from https://www1.upme.gov.co/simco/Cifras-Sectoriales/Paginas/carbon.aspx to generate a labour/production coefficient. We then used this to this to project the impact of the global transition on these regions. The impact is lower than for La Guajira and Cesar because a much lower share of coal from these regions has historically been exported. These regions will face downside risk from Colombia's transition, potentially in the 2020s, if the proposed tax reform is passed.
299. The Asociación Colombiana del Petróleo y Gas (ACP) has the best information that we are aware of about the nature and tenure of the oil and gas workforce (https://acp.com.co/web2017/es/generacion-de-empleo/generacion-laboral-por-departamentos)
300. We obtained the baseline employment for Reficar at 4,454 according to the company's 2020 sustainability report (source: https://www.reficar.com.co/Repositorio/02_GobiernoCorp/00_Biblioteca/02_ControlRendicionCuentas/GRI_%C3%9ALTIMO_22122021.pdf).
301. See https://ieefa.org/coal-divestment for a up-to-date summary of the fossil fuel divestment pledges from the global financial industry although the recent spike in coal prices has increased the risk that opportunistic providers of finance return to the sector
302. While many of the early progress in this area has happened in developed markets (see: https://www.lseg.com/resources/media-centre/press-releases/london-stock-exchange-introduces-new-climate-reporting-guidance-issuers), large emerging market stock exchanges are increasingly issuing challenging new guidance (see: https://www.jse.co.za/news/news/jse-unveils-guidance-framework-aid-progress-disclosure-and-governance#:~:text=Johannesburg%3A%2014%20June%202022%3A%20The,and%20governance%20(ESG)%20disclosure.)
303. Moody's Investors Service publishes a methodology explaining how government support is factored into "government-related issuer" ratings. Source: https://ratings.moodys.com/api/rmc-documents/64864

Table 47: **Potential ESG-related actions for different types of investors**

Financial market actor	ESG-related action	Impact on cost of capital
Investor in listed equities	Divestment, enhanced engagement	Can increase cost of equity if enough market consensus
Private equity investor	Enhanced engagement, deal restructuring, divestment	May seek increased short-term shareholder returns to mitigate long-term risk, increasing leverage for the company
Rated debt investor / rating agency	Downgraded ESG rating score, forced selling	Investors with ESG-constraints on their mandates may be forced to sell, increasing yields relative to other credits of the same rating but better ESG score. Some may refuse to participate in a refinancing.
Insurance company	Withdrawal of cover at annual renewal, increased premia	Increased insurance cost – either through premia or through risk taken on balance sheet via insurance captive
Bank	Loans offered at reduced tenor / lower leverage	Increased weighted average cost of capital because of lower leverage

4.3.8 National government: support for state-owned enterprises

State-owned enterprises with public credit ratings often receive a boost to their ratings because of government support. "Government-Related Issuers"[304] might be expected to receive additional support from governments if their own standalone creditworthiness starts to decline.

In Colombia, the government provides little in the way of explicit support (such as guarantees) for state-owned enterprises, such as Ecopetrol and Gensa (a state-owned power company and owner of coal-fired power plants). However, if those entities faced external climate transition risk that was beyond their capacity to mitigate, we would expect government to provide ad hoc support, potentially including reducing the dividend take, additional capital investments or low-cost financing.

If government were to take on all Ecopetrol's external climate transition risk, this would result in a transfer of **$13.7 billion** to the public balance sheet. This currently seems remote, given that the Colombian government has benefited in recent years from shifting risk from fuel consumers onto Ecopetrol (via the FEPC deficit), rather than the other way round.

4.3.9 National government: support for declining industries

While financial institutions – particularly international ones – may be pulling capital from Colombian transition-exposed firms, expect national policymakers and/or national agencies may seek to support those declining (and in so doing, support workers and government revenues). This would, in effect, represent the sharing of climate transition risk with the public balance sheet.

Based on the global experience of ad hoc risk sharing in commodity industries between governments and firms, this risk sharing could arise through a variety of mechanisms, including tax breaks, reliefs or holidays[305], weakening regulation for operators[306] or the provision of state-backed, discounted financing. We understand that the Agencia Nacional de Minería (ANM) is considering changing the reference for the base price in the royalty calculation for export thermal coal from the Rotterdam API2 reference to an Asian reference price. In a world where delivered prices to Asian markets were similar to European prices, this could provide a little support for miners – at the expense of local governments – because the base price for royalties is a netback to Colombia. The same delivered price, but with higher shipping costs, would result in a lower price to which the royalty percentage is applied.

304. Over the last 10 years, the UK has frequently changed the fiscal regime for North Sea oil and gas to try to preserve the economic viability of the industry. The effect of this is government taking on part of the risks that would ordinarily be borne by operators. See: https://www.endsreport.com/article/1747746/uk-government-effectively-paying-firms-operate-north-sea-oil-gas-fields
305. From our discussions with the ANM, we understand that Colombian coal mining companies are not required to pre-fund closure costs and other environmental obligations. However, these obligations, particularly the need to fund and make good mining areas after closure, have often been waived or else not enforced in South Africa and many other jurisdictions with significant mining industries. The effect of this is also for government to take on risks that should be borne by mining companies. In some cases, the risk can implicitly become socialised if mines are left abandoned (see: https://www.hrw.org/news/2022/07/05/south-africa-abandoned-coal-mines-risk-safety-rights)
306. The impact of potential early closures is already factored into the explicit risk split between firms and their workers, supply chains, local and national governments as WTW and UniAndes models automatically model an economically optimal choice

Lower revenues would result in lower royalties payable by mining firms. However, our analysis of a potential shift from an API2 reference to an Asian reference price would not be sufficient to improve the competitiveness of Colombian coal exports in a WB2C scenario. Doing so would therefore result in a transfer of **$0.5 billion** in risk from mining firms to local governments via lower royalties.

4.3.10 National government: support for municipalities facing transition risk

While the level, timing and form of government provision of support to declining industries remains subject to political considerations and therefore is difficult to predict, we would expect the national government to provide support to local governments in the event that the global transition results in structural decline in their revenues that goes beyond the resource of the stabilisation funds sized to protect against cyclical volatility.

The support that national government could provide to local governments could take multiple forms. If government takes effective measures to mitigate external climate transition risk, it could introduce reforms to the structure of local government financing, potentially involving dedicated transition funds. However, if the transition is mismanaged, national government may need to take on substantially all the climate transition risk exposure of all but the most creditworthy local governments (such as metro cities). This would amount to **$12.3 billion** (if the risk transfer contemplated in section 4.3.9. goes ahead).

Table 48 summarises the potential risk transfers set out in this section. In addition to net risk transfers of $26 billion to government, the additional items not quantified to increase that figure, if government does not incorporate climate transition risk analysis effectively into policymaking (see chapter 5).

Table 48: **Impact of implicit risk transfers on overall exposure to downside risk (NPV, $bn)**

Risk allocation	Firms / Investors	Worker and suppliers	National government	Local government	Total
Explicit risk allocation	-28.1	-35.5	-13.0	-11.8	**-88.3**
1. Renegotiate terms with supply chain	Not quantified here				
2. Earn additional revenues by selling product into new markets	Not quantified here				
3. Diversification into other products	-	-	-	-	-
4. Divest transition-exposed assets	Not quantified here				
5. Close persistently loss-making assets	Not quantified here[307]				
6. ESG	Not quantified here				
7. Support for state-owned enterprises	13.7		-13.7	-	-
8. Support for declining industries	0.5	-	-	-0.5	-
9. Support for municipalities facing transition risk	-	-	-12.3	12.3	-
Risk allocation after implicit risk transfers	-13.9	-35.5	-39	-	**-88.3**

307. As these estimates (from our data providers) relate to "decommissioning", these are likely an underestimate of "post-closure" costs including rehabilitation of land.

4.4 Contingent liabilities

However effective the strategies discussed above may prove, the ability of firms with concentrated exposures to coal mining and oil production to survive an accelerated global transition in a WB2C world will mostly be dependent on the investments that they make today. If firms continue to invest today on the expectation of a BAU trajectory, but a WB2C world emerges, not only will those firms be left with declining earnings and be overindebted, but they may suffer an accelerating withdrawal of finance. Smaller privately-held firms with limited starting access to capital – for example, in the coking sector – may in any case have limited financial flexibility, meaning that investment decisions taken in the next five years will determine firms' long-term exposure to climate transition risk.

For the firms with the largest external climate transition risk exposure – in the thermal coal and crude oil production sectors – the firms with the least resilience are those with the highest amount of climate transition risk exposure, relative to their current value and those with high leverage. As illustrated in table 49, only Ecopetrol and Canacol seem to have manageable exposure, while Cerrejón currently has the shareholders with the deepest pockets.

We built financial models to simulate how the credit profile of these companies would change, in the event of a WB2C world, but where the companies have continued to invest as per BAU. With the exception of Canacol, whose strategic focus on natural gas makes it more resilient to the global transition, all companies show marked deterioration in key credit metrics. Frontera (2028), GeoPark (2024 and 2027), SierraCol (2028) and Gran Tierra (2027) face concentrated refinancing risk in the 2020s, the viability of which is likely to be affected by the deepening integration of climate risk and ESG-related factors into decision-making. Collectively, these companies need to refinance $2.5 billion in high yield bond or bank markets before the end of 2028.

If any of these companies was to go bankrupt, not only would bondholders and bank lenders face contingent liabilities (by receiving a "haircut" on their recovery value), we expect that still further climate transition risk would fall back to the national government, via a fall in taxes, royalties (creating the need for government support of local governments, as explored in section 4.3) and, if government is unable to find an alternative licensee for the assets owned by bankrupt companies, through the need to cover closure costs. These risks would implicitly fall on government in the event of bankruptcy because mining companies in Colombia do not have to provide security or pre-fund closure costs.

We considered the impact of potential closure costs for thermal coal mines that our analysis suggested would become uneconomic in a WB2C scenario, using closure costs estimated by our data provider[308]. If all the closure costs for these mines needed to be borne by government, instead of mining firms, this would represent an effective transfer of risk from firms to government of at least **$0.4 billion** in net present value terms.

If the early closure of mines and oil fields had a serious adverse impact on the economic viability of core infrastructure, such as rail, roads, ports and pipelines, the additional burden could be even greater.

Table 49: **Starting resilience of key corporates to climate transition risk**

	VAR as share of enterprise value	Credit profile	Investment grade shareholders?
Carbones de Cerrejón	-70%	NR / no financial debt	Yes
Drummond	-81%	NR / no financial debt	No
Ecopetrol	-20%	BB+, stable	Mixed
Canacol	-20%	BB, stable	No
Frontera Energy	-95%	B, stable	No
Parex Resources	-43%	NR / no financial debt	No
GeoPark Energy	-70%	B+, stable	No
SierraCol Energy	-44%	B+, stable	No
Gran Tierra Energy	-50%	B-, stable	No

308. Historically, where governments have provided insufficient support to help manage economic transitions, there have often been long-term negative consequences for economic resilience and the strength of the social fabric (see: https://www.cam.ac.uk/research/news/former-coal-mining-communities-have-less-faith-in-politics-than-other-left-behind-areas)

Table 50: **Potential coal mining closure costs (nominal, $m)**

	Early 2020s	Late 2020s	Early 2030s
Cesar	94	300	13
La Guajira	6	-	197
Total	**101**	**300**	**209**

Finally, the question of whether government might bear additional contingent liabilities in relation to Colombian workers is a more complex one than the analysis of firms. In the growing experience of dealing with coal transitions globally, comprehensive transition plans developed in consultation with workers and supported by government (and international) funding have become a core part of what is seen to be a "just transition". In these scenarios, the cost of providing such support is, at best, an explicit commitment by government to share in the risk borne by workers and communities and at least, usually an implicit commitment[309]. Colombia has its own experience of transitions (especially in the oil industry), internal migration and internal displacement, due to conflict. This backdrop is important and has been complicated further in recent years with the accommodation of more than two million refugees from Venezuela, some of whom have become employed in coal mines closer to the border regions (for example, in Norte de Santander).

The relatively strong conditions offered by Colombian coal and oil industry jobs relative to others in certain regions – relatively formalised, relatively secure, and relatively highly paid[310] – suggests that government might need to step in to provide proactive support to workers before assets are closed. However, our analysis of changing populations in mining and oil and gas focused municipalities suggests that workers have often tended to migrate out of municipalities shortly after the closure of assets[3111]. However, it is less clear how far workers are willing to migrate to find alternative sources of employment and hence, how government support would need to be targeted in the event of asset closures. Deeper exploration of these dynamics was not possible within the scope of this project, but we believe that it needs to be a key consideration in an orderly, planned transition, enabling government to target support for workers pre-closure and preventing the collapse of otherwise fragile local economies when workers migrate away.

4.5 Systemic risk, sovereign creditworthiness, and the financial sector

The overall impact of the contingent liabilities discussed above would be to transfer further risk from those with limited risk-bearing capacity – namely small firms, workers, and communities – to government. In the case of firm bankruptcy or unexpected sudden asset closure (such as Prodeco in 2021), public budgets will potentially face a combination of higher-than-expected costs and lower-than-expected revenues.

The issues discussed above clearly represent "contingent liabilities" in the literal sense of potential obligations of uncertain size and timing. However, they are not the typical contingent liabilities budgeted for by governments, which in the case of Colombia, relate principally to guarantees and un(der)funded spending commitments[312]. As such, the contingent liabilities that we refer to are separate from those that are treated as debt-like items in analyses of public debt sustainability such as those conducted by the International Monetary Fund (IMF) and in analyses of sovereign creditworthiness, such as those undertaken by the credit rating agencies.

After all the transfers and contingent liabilities set out in sections 4.3 and 4.4, the national government could face close to $40.7 billion of climate transition risk, nearly half the total risk in Colombia.

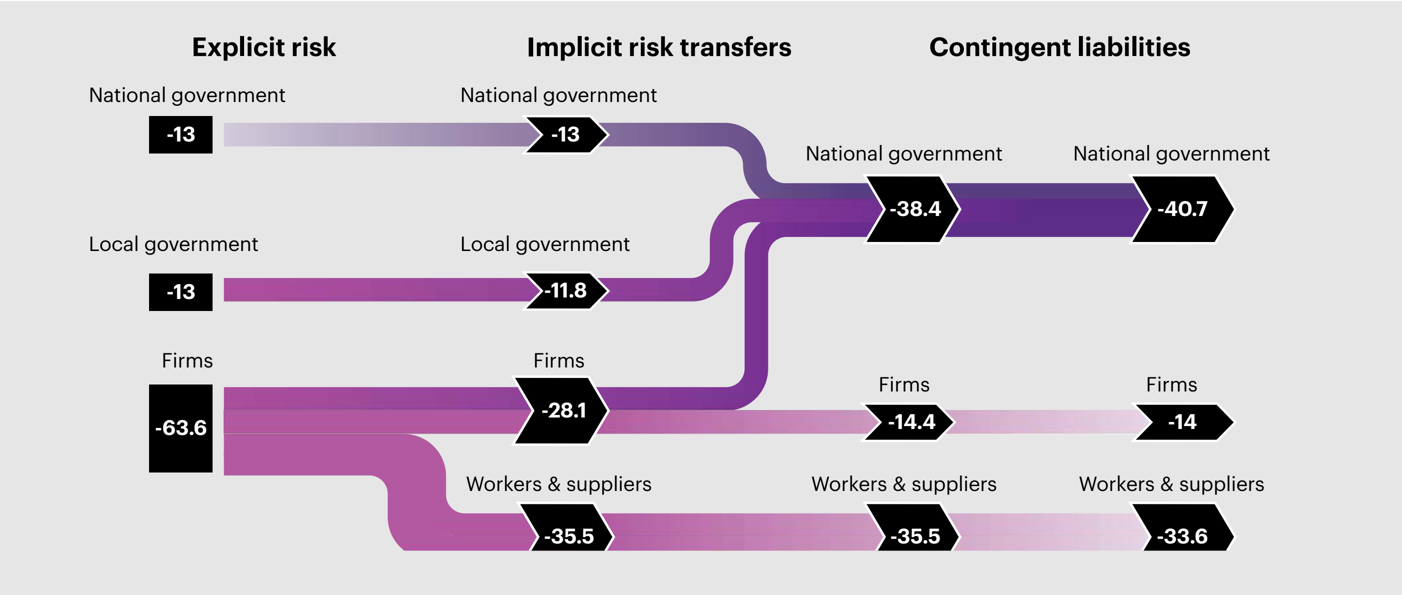
309. Using household survey data from the GEIH and the Chamber of Commerce of Barrancabermeja (source: https://colaboracion.dnp.gov.co/CDT/Desarrollo%20Territorial/Portal%20Territorial/KIT-OT/Plan-de-Desarrollo-Barrancabermeja-2012-2015.pdf) on employment type, and the extent to which surveyed workers were registered for labour risk insurance, we were able generate an estimate of the level of informality in different economic sectors for Barrancabermeja municipality. Over a period of 2017-2019, oil and mining jobs showed very low levels of informality (0.6% and 1.5% of workers surveyed, respectively), compared with commerce (73%), transportation (69%) and manufacturing (67%). This is an indicator – albeit for a single significant location, of the relatively strong employment conditions provided by fossil fuel industries and therefore, the challenge to find jobs with equivalent conditions, currently.

310. We gathered this information through qualitative research and interviews with coal industry participants in Cesar. Further anecdotal evidence has been available in the Colombia media (source: https://www.lasillavacia.com/historias/silla-nacional/la-cara-sucia-de-la-descarbonizacion-en-la-jagua-de-ibirico). Similarly, populations in municipalities, such as La Jagua had risen very sharply in the last 15 years, a trend not replicated elsewhere in Cesar department in non-mining municipalities.

311. A summary of contingent liabilities officially tracked by the Colombian government is set out here: https://www.minhacienda.gov.co/webcenter/ShowProperty?nodeId=%2FConexionContent%2FWCC_CLUSTER-165808%2F%2FidcPrimaryFile&revision=latestreleased

312. Colombian public bodies could effectively outsource some of the climate transition risk analysis for these other sectors to the companies themselves, via a climate risk disclosure mandate. However, for firm-generated information to be useful to the government in understanding the exposure of the public finances to climate transition risk, firms ought to be provided with detailed guidance as to the scenarios they should use.

Figure 31: **Summary of external climate transition risk dynamics in Colombia**



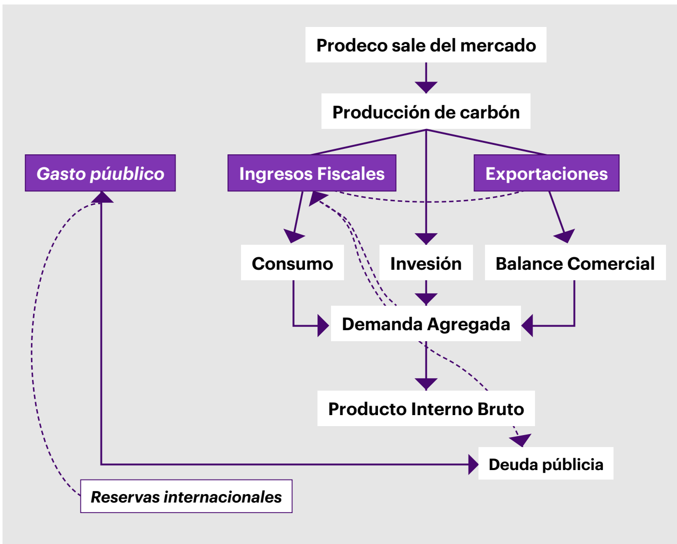
4.5.1 Secondary effects: the potential interaction of micro and macro analysis

In practice, the $41 billion set out in figure 31 above in potential national government exposure to external climate transition risk is almost certainly an underestimate. The analysis summarised in this paper was carried out with a focus on real economy sectors expected to face the highest share of Colombia's climate transition risk. However, this does not mean that other sectors (for example, real estate, gold mining) will not face climate transition risk from the same dynamics – particularly through the impact of a global transition on domestic energy prices. The impact of climate transition risk on firms in other sectors will mean an additional potential impact on fiscal revenues[313].

However, fiscal revenues will also be affected by the secondary macroeconomic effects of the risks identified in this paper. We are currently working to quantify these impacts in collaboration with a team of DNP and AFD economists who have built a GEMMES model[314] to understand the macroeconomic impact of different potential Colombian climate policy options[315].

Using the export coal sector as a pilot for the potential coupling of GEMMES and WTW-UniAndes models, we provided BAU and WB2C export volumes, revenues, and related royalties for input into the GEMMES model. The GEMMES model then calculates impacts through three principal transmission channels: 1) the trade balance, where downside risk to exports implies a depreciation of the currency and a rise in interest rates; 2) the liquidity channel, in which an increase in interest rates results in declining financial sector liquidity and lower consumption; and 3) the balance sheet channel, in which an increase in interest rates negatively impacts on investment. 2) and 3) result in a negative impact on aggregate demand and hence, for GDP. As illustrated in figure 32, public debt levels are impacted not only through the direct impact of climate transition risk on revenues from the export coal sector, but by the decline in GDP (lower profits meaning lower fiscal revenues across the board) as well as a decline in the international reserves.

Figure 32: **A schematic of GEMMES model transmission channels in relation to coal exports[316]**



313. Further information about the secondary macroeconomic impacts for Colombia of the risks identified in this paper will be published in Godin, A. et al (forthcoming, 2022)
314. Based on discussions with officials in DNP and MHCP, we are confident that similar analysis integrating the results of this paper would be possible with other national-level macroeconomic models, such as MEG4C as well as local level general equilibrium models, such as those maintained by BanRep. UniAndes academics are currently working using inputs from this study to assess secondary macroeconomic effects at the local level.
315. Reproduced with authorisation from DNP analysts from Barbosa Naranjo, S. and Hernandez Diaz, G. (2022), published in an internal DNP journal.
316. Ibid. Barbosa Naranjo, S. and Hernandez Diaz, G. (2022)

According to draft results from the DNP and AFD team, the impact of the recent Prodeco closure could reduce Colombia's average GDP growth rates by up to 40 basis points[317], resulting a 20 basis point hike in public debt. The impact of the risks highlighted in this paper, if left unmitigated, could be multiples higher.

4.5.2 Potential impacts on the sovereign credit rating

The combination of a weaker-than-expected external balance, weaker-than-expected economic activity (both nationally, and with pockets of local concentration), lower-than-expected public revenues and investment value (Ecopetrol) and higher-than-expected public costs could lead to a decline in Colombia's sovereign credit profile arising from external climate transition risk that is left unmitigated. Together, these issues could put downward pressure on Colombia's sovereign credit rating.

At the time of writing, Colombia held one investment grade rating with Moody's Investors Service (Baa2 with stable outlook) with two sub-investment grade ratings with S&P Global (BB+ with stable outlook) and Fitch Ratings (BB+ with stable outlook). S&P and Fitch had taken Colombia below investment grade in 2021 after the government withdrew planned fiscal reforms intended to stabilise the country's public debt position which had been challenged by the COVID-19 stock[318].

With the loss of two investment grade rating already meaning a constrained position with global capital markets, the impact of poorly managed climate risk could have very serious knock-on impacts[319]. We considered the impact of the risk set out above for the qualitative and quantitative metrics used by credit rating agencies to rank sovereign issuers. This analysis is summarised in table 51 below.

Table 51: **Key sovereign rating metrics (Moody's Investors Service) and the potential impact of unmitigated climate transition risk[320]**

Factor	Metric	Current Colombia assessment	Impact of climate transition risk
Economic strength	Average real GDP growth (5 year historic and projected, %)	2.9 (baa2)	Downward impact – direct and secondary effects on key real economy sectors
	Volatility in real GDP growth (%, 10 year historic)	3.7 (caa1)	As above
	Nominal GDP ($bn)	270.3 (a2)	As above
	GDP per capita (PPP $bn)	14,473 (baa3)	As above
Institutions and governance strength	Quality of legislative and executive institutions	baa	N/A
	Strength of civil society and the judiciary	ba	N/A
	Fiscal policy effectiveness	baa	Could be marked down if climate risks not actively managed
	Monetary and macro policy effectiveness	a	Could be marked down if climate risks not actively managed
Fiscal strength	Government debt / GDP	67.2 (ba1)	Downward impact – higher debt and lower GDP
	Government debt / Revenue	258.3 (ba1)	Downward impact – higher debt and lower fiscal revenue
	Government interest / Revenue	11.2 (baa2)	As above
	Government interest / GDP	2.9 (baa2)	Downward impact – higher debt and lower GDP

317. Source: https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/s-p-downgrades-colombia-to-junk-after-government-withdraws-reform-proposal-64422393
318. As sovereign ratings get weaker within sub-investment grade, country issuers not only face escalating borrowing costs but can also face increasingly uneven access to global capital markets full stop, especially in periods of global crisis.
319. Source: https://www.moodys.com/credit-ratings/Colombia-Government-of-credit-rating-186200/summary
320. All sovereign issuers face a tail risk from future changes in approach to climate risks at rating agencies, international financial institutions as international pressure to incorporate climate risks into their analysis increases.

As climate transition risk is likely to crystallise over time, so economic and fiscal strength metrics could deteriorate gradually. However, as rating agencies gradually start to incorporate climate risk considerations more systematically into sovereign ratings, there is an increasingly high chance that sovereign issuers start to be penalised or positively incentivised via the quality of their climate risk management policies and regulations[321]. A downgrade in qualitative scores may be more likely to trigger a downgrade sooner as it would likely change the rating agency's opinion on what level of public debt is sustainable at the current rating level. Rating agencies tend to equate weaker policymaking and regulatory environments with domestic volatility and hence, lower debt capacity, compared to countries with stronger and more consistent policymaking.

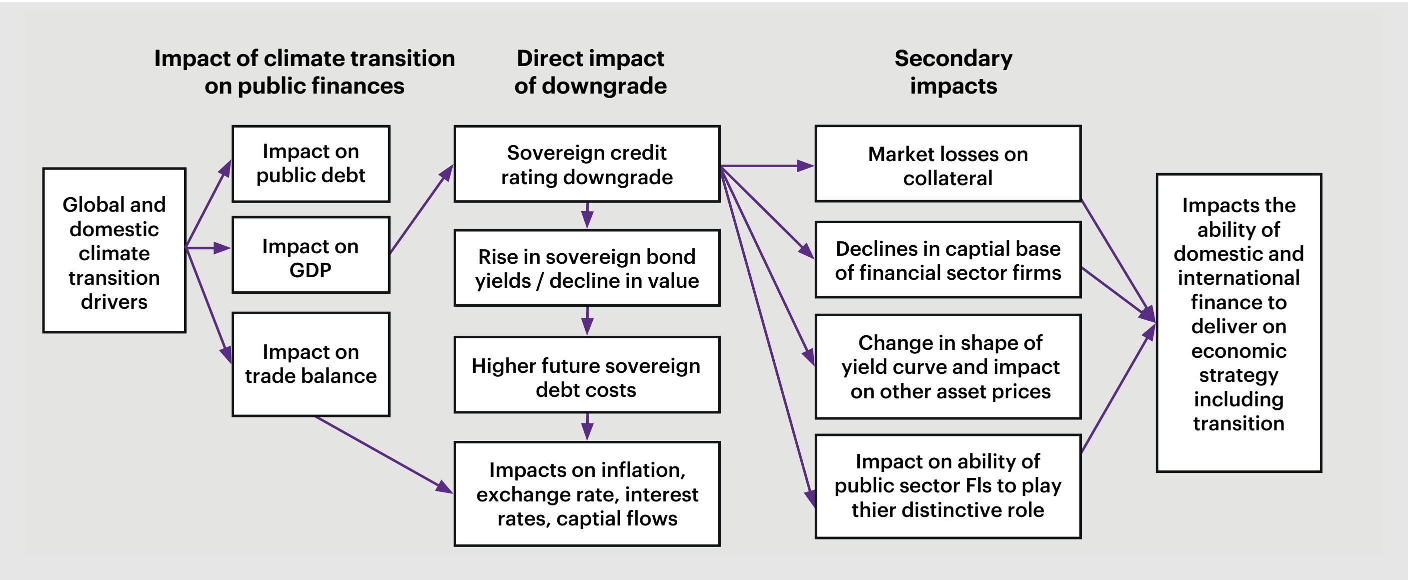
4.5.3 Impacts of a sovereign rating downgrade on the Colombian financial system

As we explored in a parallel paper[322], a decline in sovereign creditworthiness could have a material impact on the Colombian financial sector. As illustrated in figure 33, a decline in sovereign creditworthiness, as witnessed in 2021 in the months preceding and following Colombia's loss of two of its three investment grade sovereign credit ratings[323], could have a variety of dampening effects on Colombian economic activity and inward investment, although the extent to which it could pose a threat to financial stability will also depend on the external environment at the time of the downgrade.

We simulated the impact of a potential multiple notch downgrade of Colombia's sovereign rating starting in 2031 and found that while up to $6.6 billion in market value losses would accrue to Colombian and international holders of sovereign credit, the value of more than $44 billion of non-sovereign peso-denominated could also face downside risk due to the increase in the level and shape of the Colombian yield curve that would arise in the event of a downgrade. The recent negative returns on Colombian fixed income instruments as inflation has spiked, is indicative of the market-wide impact of a change in the risk-free yield curve[324].

Sovereign-related climate transition risk is a mostly underappreciated source of exposure for Colombian financial institutions across the system. In fact, it may be the largest source of external climate transition risk. Across the companies in the sectors reviewed in chapters 3 and 4, Ecopetrol is the largest company facing downside risk with shares or bonds listed in Colombia, while Paz del Rio could stand to benefit in the short term despite long-term challenges from the domestic transition (see section 5.4)[325]. Colombian financial institutions appear to have much greater exposure to sectors affected primarily by domestic transition risk, as explored in chapter 5.

Figure 33: **Mapping of systemic implications of a climate-related sovereign downgrade**



321. See forthcoming: Huxham, M. (2022) Measuring and managing the sovereign-related climate transition exposure of the Colombian financial system
322. Colombia's sovereign credit spreads did widen after the country lost its second investment grade credit rating, with macroeconomic implications as explored in (see: https://ideas4development.org/en/colombia-caught-in-financial-turmoil/). However, as explored in more depth in Huxham, M. (2022), this spread widening compared with other emerging market sovereign bonds began before the downgrades. The short-term impact of the downgrades more gradual, than sharp, given that the only gradual reduction in the weighting of Colombian bonds in key emerging market debt indices, which are a key influence of the behaviour of most foreign investors in Colombia.
323. Inflation has hit returns on fixed income across the board in 2022, but emerging markets face a potential double whammy, exacerbated by currency depreciation. For a good summary, see: https://www.ubs.com/co/en/assetmanagement/insights/asset-class-perspectives/fixed-income/articles/brace-long-hot-summer.html
324. Paz del Rio was acquired by Colombian private equity firm Trinity Capital in late 2021, however it has maintained its Colombian stock exchange listing for at least the short term (see: https://www.infobae.com/america/colombia/2022/01/19/acerias-paz-del-rio-no-dejara-la-bolsa-de-valores-de-colombia-y-retornara-a-manos-colombianas/)
325. Source: EMIS

While we were not able to access portfolio-level data, we ascertained from publicly available financial statements that coal companies based in La Guajira and Cesar have limited financial debt[326]. By contrast, we expect Colombian banks to provide services[327] to companies in the coal value chain (including infrastructure), oil and gas companies, and the oil and gas value chain. We were not able to ascertain the magnitude or tenor of these facilities, but unless they have a tenor lasting into the period that we have identified as a concentrated period of climate transition risk, it is likely that Colombian banks have limited exposure to Colombia's external climate transition risk. What may then be a greater determinant of financial sector exposure to these risks is the actions that financial institutions take in the coming years. There is currently a growing trend in financial markets around the world and at a very initial stage in Colombia, to promote the use of lending instruments that could support the climate change transition of the corporate sector[328]. An increasingly important new methodology, being developed globally but also by the authors of this report, points to the role that finance has to play in ensuring that any global and domestic transition is orderly, and not disorganised in a way that actually destroys economic value en route to a WB2C future.

In this sense the recent launch of Colombia's green taxonomy (for both public and private spending) could prove an excellent foundation for Colombian financial institutions to start shifting their portfolios towards climate mitigation and towards reducing climate transition risk in their own portfolios, but also providing signals to firms to start incorporating transition risk assessment in strategic decision making. By providing clear national guidance on what do and do not constitute "green"[329] exposures, the taxonomy can and should also incentivise engagement by both Colombian and international financial institutions with investee companies and bond issuers on their transition plans – including the national government. However, because climate transition risk (particularly external climate transition risk) does not neatly correlate with the taxonomy, unless Colombian financial institutions consider climate transition risk as a separate issue, they may deprioritise investments that increase systemic resilience that might not meet the criteria or might meet the criteria and may offer greater additionality (for example, supporting the decarbonisation of the brick or the glass industry) than investments in wind and solar farms.

4.6 Conclusion

At $88 billion, the magnitude of Colombia's external climate transition downside risk exposure is material. As explained in section 4.5, this number is likely a significant underestimate of the overall risk, given the secondary macro effects arising from the impact of a weakening trade balance and declining fiscal revenues. In addition, the analysis has only paid qualitative consideration to one of what may be the most pernicious external transition threats – the increasing volatility that is likely to arise from an increasingly disorderly global transition[330]. These are critically important areas for further investigation.

Just as important as the size of the risk is the concentration of this risk in time (the majority could crystallise over ten years between the late 2020s and the early 2030s), in place, and within economic groups. With more than $40 billion potentially falling on the national government balance sheet, there could be a wide series of knock-on impacts for the Colombian economy and financial system. However, unlike in many European and North American countries, the relatively small size, strong capitalisation and limited direct exposure of the Colombian financial system to the real economy sectors facing external climate transition risk means that the threat posed by climate transition risk to the Colombian financial system may be lower than imagined in much of the literature published by the NGFS and aimed at economies with more tightly-wound financial systems.

Failure to manage the issues discussed in the last two chapters could also lead to social unrest that reduces consent for Colombia's domestic transition. However, as is discussed in the next chapter, Colombia still has time to grasp the important opportunities arising from an accelerated Colombian transition fast enough to meet the stretching goals of the E2050 target. This transition could also, as analysis to support the E2050 shows, result in significant economic cost not planned effectively. If planned well, it can partially help policymakers square the circle of issues posed in these chapters – the need to maintain economic growth and social stability while implementing a radical structural economic transformation which simultaneously generates new and more sustainable sources of growth while also going a long way to mitigating the systemic risks inherent in Colombia's exposure to the global transition.

326. Most likely short-term financing, liquidity facilities (such as revolving credit facilities) and contingent facilities (such as guarantees and letters of credit)
327. These products, which in reality are heterogeneous, are often loosely described as "transition finance" (source: https://blogs.lse.ac.uk/businessreview/2022/03/22/where-are-the-people-in-transition-finance/#:~:text=A%20relatively%20new%20tool%2C%20transition,that%20already%20meet%20green%20standards.)
328. Unlike the EU sustainable finance taxonomy (see: https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en), Colombian's green taxonomy excludes natural gas and nuclear (see: https://www.responsible-investor.com/colombia-launches-first-latam-green-taxonomy-excludes-nuclear-and-gas/). Full information about Colombia's taxonomy is set out here: https://www.taxonomiaverde.gov.co/webcenter/portal/TaxonomaVerde
329. For an in-depth exploration about disorderly scenarios, please see the essay Risk modelling: how to embrace these disorderly transitions by Nelson, D. in https://www.wtwco.com/en-US/Insights/2022/04/energy-market-review-2022
330. Source: https://www.theccc.org.uk/about/

5. Options to minimise the impact of climate transition risk

Key messages:

1. This paper identifies climate transition risk in Colombia as potentially destabilising if not tackled proactively. Colombia has a range of options, but the government needs to be proactive, as continuing the current trajectory could result in new investments that increase the size of the risk
2. Embedding climate transition risk analysis within Colombian policymaking, regulatory, and investment decision-making processes will be key to enabling a low-cost orderly transition. Doing this effectively should be a joint endeavour between government, firms, academia, and civil society.
3. Colombia potentially has significant short-term opportunities in agricultural exports and longer-term opportunities in transition metals and hydrogen derivatives. However, by themselves, these are not likely to be sufficient or to materialise early enough to offset all the risk.
4. As Colombia designs implementation plans to meet NDC and E2050 goals, it should consider how certain domestic transition pathways can help mitigate the risks identified in this paper, in particular, accelerated transitions in transport and industry that reduce future imports of oil and gas and hydrogen-heavy transitions.
5. Maximising the previous two recommendations would reduce the cost of mitigating Colombia's climate transition risk exposure. Colombian policymakers should target new sources of fiscal revenue and international funding to help provide targeted support for parties with limited risk-bearing capacity. purpose.

5.1 Introduction

Colombia faces a series of strategic challenges that will affect the sectoral and broader economic policy choices that that governments in the upcoming years. Managing an economy-wide transition in line with the E2050 vision is a complex enough task, but a mismanaged (or worse, unmanaged) exposure to external transition risk might put at risk Colombia's economic stability. These risks could be overwhelming at the local level, in parts of the country with limited risk-bearing capacity, such as coal mining in La Guajira. However, they also have systemic consequences, with risk to Colombia's external balance, sovereign credit rating, financial institutions and to the viability of an economic model that is heavily reliant on extractive industries.

In addition to the detailed diagnosis of Colombia's climate transition risk exposure, the authors have conducted analysis to understand the options that Colombia has to mitigate or otherwise offset the risks set out in the rest of this paper. We conclude that Colombia does have alternative pathways to sustainable and resilient economic prosperity, even as the dynamics of global transitions increasingly add volatility to the international context. We believe that this chapter will be relevant not only for policymakers and regulators, but also for the real economy firms, financiers and civil society organisations who will be at the forefront of shaping and driving Colombia's domestic low carbon transition.

Our understanding of Colombia's options was informed not just by analysis, but also by the interviews undertaken while performing the analysis; and by the authors' own experience analysing climate transition dynamics outside of Colombia. A comparison with other countries' current economic structures, can be instructive when comparing decarbonisation strategies. Much developed world climate action has implicitly been delegated to the private financial sector, with climate-related financial regulation and disclosure requirements being used to incentivise financial sector firms to put pressure on their real economy counterparties to change their strategic course towards low carbon. The large size and importance of European and North American financial sectors relative to the countries where their operations are based, and the role that those financial sectors play globally in financing carbon intensive activities, has contributed to a growing concern that unmitigated climate risk could pose a threat to financial stability. By contrast, in Colombia, where the size of financial markets and banking books is relatively small compared to Europe and North America, financial institutions face less direct exposure to transition-impacted sectors, but very significant exposure to Colombia's sovereign debt position. It may therefore follow that climate-related financial stability challenges in Colombia are more likely to be linked to economic, fiscal space, and social stability challenges, rather than major risk exposures to transition-impacted in the financial sector itself. What this means is that for Colombia to design an effective climate transition risk mitigation strategy, it should proactively tackle the economic, fiscal, and social challenges highlighted in the preceding chapters.

This structure of this chapter is designed around four main themes arising from the analysis: 1) the risk of a persistent structural decline in Colombia's external balance arising from the global transition; 2) the potential impact of external transition risk on domestic transition policy choices; 3) the concentration of downside risk in assets, sectors, geographies and groups of workers who may not have obvious options for risk mitigation and the systemic implications of that risk "misallocation"; and 4) the changes in the structure of policymaking that would be needed to help track and manage issues 1, 2, and 3, as well as the uncertainties relating to the development of low carbon systems.

From these themes, we have developed four main sets of recommendations, each of which is explored in a separate section of this chapter.

1. Embed an understanding of climate transition considerations into Colombian policymaking, firm strategy, investment flows, academic research, and civil society action (section 5.2)
2. Prioritise growth (either as part of a domestic low carbon transition or to take advantage of global trends) of economic sectors (either new sectors or expansion of existing activities) with large-scale export potential. These issues are explored in section 5.3.
3. Adopt domestic transition policies that support the mitigation of external transition risk (section 5.4)
4. Proactively target groups and regions with concentrated downside risk with funding and other support (section 5.5)

In each sub-section, we provide a detailed set of recommendations targeted principally at policymakers and public bodies. However, we would expect all the recommendations to be relevant for real economy firms, financial institutions, academia, and civil society, all of whom should have an interest in ensuring that policy and regulation take appropriate account of these issues.

5.2 Embed an understanding of climate transition considerations into Colombian policymaking, strategy, and investment flows

The subsequent sections of this chapter lay out an argument for how Colombia can mitigate the potentially destabilising risks highlighted in chapters 3 and 4, including the proactive pursuit of diversification in Colombia's exports; using the domestic transition to mitigate external transition risks; by targeted mitigation of risk concentrations; and judicious use of emerging international sources of climate-focused funding. However, the country will not be well placed to do these things unless it takes action to embed an understanding of climate transition considerations – both domestic and global - into policymaking, firm strategic decisions, investment flows, academic research, and civil society action. If it does not do this urgently, it is likely that more public and private investment will continue to flow into long-life assets with characteristics not consistent with a WB2C scenario, and in so doing, add further to Colombia's already sizeable exposure to climate transition risk. Adding more transition risk would increase the cost of Colombia's transition. By contrast, limiting climate transition risk exposure can help Colombia increase its economic resilience and help meet its development goals, even in the face of the global structural changes posited in this paper.

This section sets out our recommendations as to how Colombia can embed climate transition risk analysis into decision-making. We argue that, to do this effectively, policymakers ought to do the following:

a. Develop Colombia-based capacity that allows policymakers to update and improve on these analyses as the nature of climate transition risk and climate transition risk mitigation options become better understood. Adding a comprehensive analysis of the implication of physical climate risk will also be important to get a better understanding of Colombia's likely economic standing as it starts to deal with transition-related challenges

b. Use the scenarios and insights developed by this project to assess the resilience of current and planned policies, regulation, and public investment to climate transition risk, considering the microeconomic impact on productive sectors and regional economies as well as macroeconomic and financial system ("system-level") issues

c. Accelerate detailed analysis of potential transition pathways for domestic sectors (particularly industrial sectors) not covered in detail in this report; the trade-offs inherent in different technology choices; and their implications for cross-sectoral infrastructure planning

d. Enhance public transparency as to the data, scenarios, and detailed policy priorities underpinning Colombia's deep decarbonisation plans over the period to 2050

e. Introduce new policy and regulatory measures designed to attract additional international investment into Colombia and to ensure an orderly shift in capital flows from sectors expected to face decline to those resilient to or benefiting from a transition

Implementing these recommendations would help Colombia reduce the cost of meeting its E2050 goals and increase the chance of sustainable growth and broad-based prosperity in the coming decades.

Table 34: **Mapping of systemic implications of climate transition risk in Colombia**

Embed an understanding of climate transition considerations into Colombian policymaking, firm strategy, investment flows, academic research, and civil society action	
A. Building capacity in and awareness of climate transition risk issues – global and Colombia-specific	
1. Continue to procure independent advice on climate transition issues (including on climate transition risk, climate transition scenarios, low carbon technologies and approaches to repurposing fossil fuel infrastructure and rebuilding post-fossil fuel communities), drawing on both international and Colombian expertise. This advice and the research underpinning it should not be guided by real economy industries with an economic interest (downside or upside) in the design of Colombia's low carbon transition	**DNP, MME, MADS**
2. Consider setting up an independent institution (or an independent part of an existing institution) with a legal mandate to provide advice to government on transition issues.	**DNP, MME, MADS**
3. Continue to provide support in efforts to provide training to Colombian policymakers, real economy firms, financial institutions, academia, and civil society on climate transition scenarios	**DNP, MHCP, MADS, Colombian academic institutions**
4. Develop Colombia-based dedicated climate transition modelling capacity	**DNP, Colombian academic institutions**
5. Develop a comprehensive understanding of physical climate risk that is compatible with this analysis of climate transition risk. Understanding these risks better and taking action to build resilience to them would further enhance Colombia's future sustainable development prospects	**DNP, MHCP, MADS, Colombian academic institutions**

B. Use the data and analysis from this study to "stress test" current and planned policies, regulation, and investment plans	
6. Design and complete a cross-government macroeconomic and financial system stress test (building on the work already undertaken by BanRep and SFC) for a scenario with an accelerated decline of coal production (and revenues), coal power and crude oil production (and revenues) in the next ten years	**MHCP, DNP, BanRep, SFC**
7. Incorporate medium-term climate transition considerations into budgetary planning and assessments of public debt sustainability. Publish the results alongside budgetary documents	**MHCP**
8. Develop processes to manage climate transition risk and its potential impact on sovereign debt – hence avoiding what would otherwise likely be an increase in the cost of capital	**MHCP**
9. Develop a process for managing, monitoring and, where appropriate, provisioning against climate risk-related contingent liabilities to the public balance sheet	**MHCP, SFC, BanRep**
10. Make climate transition risk analysis a mandatory part of the due diligence process for major public investment decisions, including those by state-owned enterprises. This could help to avoid spending public money on new investments that increase Colombia's climate transition risk exposure.	**MHCP**
11. Make new licenses (or license extensions and renewals) relating to coal, oil, and gas subject to enforceable funding commitments around closure and post-closure costs. This could avoid implicit (and unbudgeted) transfers of climate transition risk from private sector firms to government.	**MME, ANH**
C. Accelerate detailed analysis in relation to support decisions around key uncertainties underlying Colombian climate policy	
12. Accelerate initial climate transition analyses for issues out of the scope of this report: CCUS – technical viability and costs	**MME, DNP**
13. Accelerate initial climate transition analyses for issues out of the scope of this report: cross-cutting AFOLU emissions mitigation and climate transition analysis	**MinAmbiente, DNP**
14. Accelerate initial climate transition analyses for issues out of the scope of this report: biofuels and biomass – including an assessment of which sectors to prioritise	**MinAmbiente, DNP**
15. Accelerate initial climate transition analyses for issues out of the scope of this report: "clean firm" generation. Conduct a review of the current electricity market regulatory framework drawing on international examples of the challenges of moving from a "capacity"- to "flexibility"-based system	**MME, DNP**
16. Develop techno-economic studies, drawing on the best international examples, on the relative costs of low carbon technology options in sugar refining, pulp and paper, textiles, and chemicals industries. Develop transition pathways for these sectors incorporating uncertainty about the future costs and availability of CCUS and circular economy strategies.	**MME, DNP, MinAmbiente, ANDI**
17. Develop a model for cross-sector infrastructure planning and investment requirements in different climate transition flows	**All, led by DNP**
18. Conduct research into alternative Colombian economic models with significantly reduced dependence on fossil fuel rents	**MHCP, BanRep**

D. Enhance public transparency about the data, scenarios, and detailed policy priorities underpinning Colombia's long-term deep decarbonisation plans	
19. Develop publicly available common scenarios and data to be used for "stress testing" and scenario analysis across public sector, financial institutions, and private real economy corporates	**DNP, MHCP, SFC, BanRep**
20. Develop and consult on a policy and regulatory toolkit of options that could be used by public bodies to accelerate a Colombian transition, including regulatory changes (for example, including an emissions performance standard for new power generation); legislative phase-out dates (for example, for unabated coal-fired power generation); outright bans, including those with a phase-in date (such as in relation to internal combustion engine vehicles; fiscal incentives and disincentives (such as carbon pricing); provision of low cost public or public-backed financing for low carbon developments (for example, through public development banks) and wholesale market design changes (for example, in the electricity system)	**DNP, MME, MHCP, MADS**
E. Facilitate an orderly shift of capital flows from sectors expected to face decline in a transition to those expected to be resilient to or benefiting from a transition	
21. Accelerate requirements and guidance for transition plans and reporting for thermal power generators (including information about coal and gas procurement contracts), coal miners and oil and gas production companies.	**MME, MHCP**
22. Use (and potentially extend) the green taxonomy as a means to direct public and private spending towards transition opportunities and mitigation of transition risks	**DNP, MinAmbiente, MHCP**
23. Accelerate requirements and guidance for climate risk management and reporting in Colombian financial institutions including public financial institutions	**SFC**
24. Consider the applicability for the Colombian context of financial regulatory options for mitigating climate risks being developed by the world's central banks and financial regulators, including differential risk weightings for assets and asset classes facing climate risk exposure; differential capital requirements for firms based on the strength of their climate risk management practice and the application of systemic risk capital buffers	**SFC, BanRep**

5.2.1 Building capacity in and awareness of climate transition risk issues – global and Colombia-specific

Colombia's climate transition risk exposure will change over time as the shape of the global transition becomes clearer and Colombia takes actions to pursue its own transition. In future, as recommended in this chapter, Colombia might systemically incorporate a consideration of climate transition risk into decisions about domestic policy.

However, to do this effectively is likely to require the development of more dedicated expertise in climate transition modelling in Colombia than we are currently aware of at today. Based on experience in other markets, we believe that it will be important that investors and civil society believe that this analysis is independent both from government and from the interests of any one industry group. For these reasons, we would recommend setting up an independent institution or part of an existing independent institution (such as a university) with independent funding (or at least independent governance) and a mix of relevant technical skills and with an explicit mandate to provide advice to government on climate issues. This institution could draw on the expertise of existing government bodies, such as SISCLIMA and UPME, but with independence from those organisations. One institutional example for such a body would be the UK Climate Change Committee, which has a role specified to legislation to scrutinise government policy against carbon budgets set in law[331].

331. The PIGCCme (2022) requires companies in the Colombian mining and energy sectors to develop transition plans by 2024

Apart from the additional work proposed in the sections below in relation to transition risk, we would propose that the government (or the new climate analysis institution proposed above) commissions new analysis or incorporates existing analysis on physical climate risk into a combined picture at microeconomic and system level with climate transition risk. Hitherto poorly understood physical risk could place additional pressure on the risk-bearing capacity of the parties referenced in this report, increasing the risk that poorly managed external climate transition risk could provoke economic destabilisation.

5.2.2 Use the data and analysis from this study to "stress test" current and planned policies, regulation, and investment plans

A principal aim of this study has been to develop insights, data and scenarios that will add value to Colombian policymaking. To do this, the authors have highlighted certain gaps in Colombian policy in relation to climate transition risk and sought to fill some of these gaps through the analysis summarised in this paper.

We would recommend a period of detailed socialisation and consultation with real economy companies and the financial sector about the implications of this work and to develop a common understanding of the approach, the data, the assumptions, and the uncertainties. This could then help to generate a series of tasks for the incorporation of the climate transition scenarios used in this study into future policymaking and financial regulation.

The authors have already worked closely with officials from the project's steering committee member to identify areas in the short term, where the analysis from the report could be used to "stress test" current and planned policies, including those in the Plan Nacional de Desarrollo. Potential items where the analysis could be particularly useful include a) the assessment of the climate transition risks relating to new rail infrastructure; b) the assessment of the impact of a potential decline in Colombian oil production and the global low carbon transition on fiscal sustainability; c) the assessment of systemic risk for macroeconomic and financial systems. A clear potential area of applicability is in defining scenario parameters for public bodies to use with their stakeholders when requesting transition planning[332].

5.2.3 Accelerate detailed analysis in relation to support decisions around key uncertainties underlying Colombian climate policy

The study was carried out during a period of significant change in Colombian climate policymaking. This was also a period in which the speed and shape of Colombia's energy transition became an object of heated public and political debate. In particular, the authors observed and reviewed public claims and counterclaims about fracking and shale oil/gas; arguments about the speed and decline of Colombia's oil and gas production and the costs and benefits of Colombia's self-sufficiency in energy commodities. Ultimately, the debate about the potential costs, risks, dangers, and ethics of an accelerated transition or changed economic model in Colombia are manifestations of a broader trend being witnessed in many large emerging economies. However, this study clearly shows that a slower transition that entrenches the bargaining power of incumbent industries, is likely to be one which results in the greatest economic and financial downside risk for Colombia.

To bring light to a debate that has generated a lot of heat, we propose that the Colombian government accelerates plans set out in recent policy documents to turn its E2050 vision into detailed implementation plans for each key productive sector, including the microeconomic implications for workers and regional economies and related macroeconomic and financial stability implications. To ensure that the research is perceived to be as independent from sectoral and political interests as possible, this research could be conducted by independent institutions recommended above.

Table 53 sets out some of the key sectoral and cross-cutting areas of uncertainty where accelerated research and analysis will be critically important to help create broader understanding of transition challenges. These are explored in more detail, in turn, below.

332. "First generation" biofuels typically refer to those generated from products whose growth may conflict with other important land uses, such as for food. Current Colombian biofuel production from ethanol (itself produced from sugar cane) and palm oil are in this category. Second and third generation biofuels increasingly use advanced gasification (rather than combustion) technologies with food-based feedstocks and progressively move towards the use of non-food based feedstocks, including those based on waste.

Table 53: **Unresolved issues for urgent study**

Urgent issue for further study	Sector-specific or cross-cutting	Current sources of uncertainty
Carbon capture, utilisation, and storage (CCUS)	Cross-cutting	Underpins viability of continued long-term use of natural gas in Colombia, but very little understanding of geological storage potential and infrastructure costs
AFOLU emissions reduction plan	Cross-cutting	Pace of Colombian decarbonisation in non-AFOLU sectors depends on successful conversion of AFOLU sectors from Colombia's biggest source of GHG emissions to a net sink.
Biofuels and biomass	Cross-cutting	Viability of scaling up land use targeted at biomass and first-generation biofuels, given challenges to reduce AFOLU emissions. Long-term viability of first-generation biofuels and practical challenges with scaling up second and third generation biofuels[333] (including links with waste sectors). Understanding of which sectors to prioritise given limited biofuel supply
Options for flexible "clean firm" power generation	Sector-specific	Current Colombian planning assumption that some form of coal- or natural gas-fired power will be required in 2050 does not accord with international developments on "clean firm" power. Decisions on "clean firm" power will impact CCUS plans
Decarbonisation pathways for industrial sectors	Sector-specific	Policy planning for liquid fuels, coke, steel, cement, and other industrial sectors needed to help drive decarbonisation investment and to make explicit potential trade-offs between cost and security of supply
Infrastructure planning	Cross-cutting	Required size, location, and timing of new network investments (electricity, gas, hydrogen, CO2) will be different depending on sectoral plans
Alternative economic models with less reliance on fossil fuel rents	Cross-cutting	For an orderly transition to a new economic model, understanding the trade-offs of potential alternatives will be key

5.2.3.1. CCUS

The physical and economic potential of CCUS in Colombia is one of the biggest uncertainties about our alternative decarbonisation scenarios and about Colombia's current energy transition policy. The hitherto limited global historic deployment of carbon capture[334] has led most emerging international deep decarbonisation models to try to limit the application of CCUS to sectors where clean electricity or hydrogen are not considered to be potential technological substitutes[335]. This would mean focusing CCUS investment in large-scale "hard-to-abate" industrial processes such as clinker production for cement. By contrast, in Colombia, there appears to be an implicit assumption that CCUS will be broadly available for use across power and industry. Implicit in the promise of natural gas as a "transition fuel" in power and industry is an assumption about the deployment of CCUS on a timely basis and at reasonable cost. The current evidence base for the planned long-term use of fossil fuels in Colombia (and therefore, for the viability of a natural strategy using natural gas as a "transition fuel") is very limited and should be subject to urgent scrutiny.

According to the E2050 vision document, as well as reaching "net zero" greenhouse gas emissions by 2050, 90% of the differential in greenhouse gas emissions compared with 2015 would relate to absolute emission reductions, with only 10% (or up to 24mt in 2050[336]) relating to offsets or "absorptions". Given the potentially important role that nature-based offsets could play in

333. https://energypost.eu/will-this-be-the-decade-of-carbon-capture-or-another-false-start/
334. UK false starts on CCUS: Demo 1: https://sequestration.mit.edu/tools/projects/longannet.html. Second competition: https://www.theguardian.com/environment/2015/nov/25/uk-cancels-pioneering-1bn-carbon-capture-and-storage-competition
335. WTW / UniAndes calculation compared with gross 2014 emissions

reducing net AFOLU emissions, the E2050 factors does seem to allow continued long-term, unabated use of coal or gas in any mining, energy, or industrial sub-sector. The E2050 document estimates that from today's emissions, only 6 million tonnes per annum would be suitable for capture – either today or in 2050 – without the introduction of new technologies (such as enhanced oil recovery or EOR) or structural change and greater co-ordination (such as industrial clustering)[337].

Understanding the potential volume of CO2 available to be captured, transported, and stored, is critical to the assessment of the relative economics of CCUS as a mitigation technology, relative to others and we welcome the studies and pilots currently planned by Colombian institutions in relation to these issues[338]. The extent of CO2 transport and storage infrastructure cost payable by any given power plant or industrial facility will depend on the volume of CO2 expected to be injected into the infrastructure system and over which potentially significant initial capital costs can be amortised. EOR, which uses CO2 to help recover previously uneconomic oil deposits, will not help in this regard, as it traps CO2 in the wells from which oil is being recovered, rather than transporting and storing it in centralised common infrastructure. By contrast, "blue hydrogen" (made from natural gas via steam methane reforming, with CO2 captured and stored), could potentially be such an "anchor" source of CO2, which could help to de-risk investment in common CO2 transport and storage infrastructure and in so doing, bringing down the costs of using the technology with new or existing Colombian power plants or industrial facilities.

In this model, Colombia would develop the easier-to-deploy green hydrogen projects to replace "grey" hydrogen[339] in some industrial processes and to displace some oil-based fuels transport applications. Blue hydrogen pilots would then, in theory, follow in the 2030s. At that point, the two methods of producing clean hydrogen could compete for economic viability, with the cost of green hydrogen being dependent on the extent to which global deployment has brought down the cost of electrolysers and renewable electricity installations while the cost of blue hydrogen, will be dependent to a large extent on the price of natural gas (which per chapter 3 would go up if domestic prices become more closely linked to international prices). Blue hydrogen producers would then face additional costs relating to the cost of capture, transport, and storage per unit of CO2 captured plus the impact of any carbon price on residual uncaptured emissions[340].

For now, all we have in the Colombian context is the cost estimates in the E2050 showing capture at $15-60 per tonne for the purest streams of CO2. Transport costs could add a further $1-15 per 250km of pipeline with storage costs adding a further $2-31 per tonne of CO2[341]. A full chain cost of $20 per tonne captured would represent the absolute best-case scenario and is what is assumed by the hydrogen roadmap[342]. At the upper bound, full chain CCUS costs could be nearly five times as high. For industrial users of natural gas, CCUS costs could more than double the cost of using gas as a fuel (at the upper bound) .

Table 54: **Gas costs for a Colombian electric arc furnace in 2030, with and without CCUS**

Annual steel production	Mt	0.47
Gas required to product one tonne of rebar	GJ/t	0.3
Carbon emissions to produce one tonne of rebar	tCO2e/t	0.18
Gas price in 2030	$/mBTU	9.5
Annual gas cost prior to CCUS	**$m**	**4.9**
Annual CCUS full chain cost, lower bound	$m	1.6
Annual CCUS full chain cost, upper bound	$m	7.2
Annual gas cost with CCUS, lower bound	**$m**	**6.5**
Annual gas cost with CCUS, upper bound	**$m**	**12.1**

336. Source: https://e2050colombia.com/wp-content/uploads/2021/11/2050_Libro_final_digital_baja_compressed.pdf
337. We understand from conversations with Colombian officials that there are studies already ongoing to help understand the geological potential of CO2 storage and the potential future business models and regulatory frameworks that could arise if Colombia were to develop CCUS at scale
338. Produced from fossil fuels without carbon emission abatement
339. The IEA's report on CCUS points out that "capturing 100% of the CO2 is often prohibited by thermodynamic laws", adding that very high rates of capture often require larger air separation units and higher energy costs per unit captured. This means that capture costs can get much more expensive the higher the intended capture rate. This means that pretty much all facilities with CCUS will have residual emissions, which will attract an additional carbon cost. Source: https://www.iea.org/reports/ccus-in-clean-energy-transitions/ccus-technology-innovation
340. Source: E2050 (2021)
341. Source: Hoja de Ruta del Hidrógeno (2021)
342. See chapter 2 for an analysis of AFOLU emissions

The implication of this high-level analysis is that it would only make sense for the steel plant to invest in CCUS if it expected a carbon cost higher than the full-chain cost of CCUS per tonne captured. As set out in the WB paper, an economy-wide carbon price of $60-$70 per tonne at the upper end of our estimates would likely be economically destructive and, we assume, would be unlikely to happen. A tax at the lower bound could be viable.

What this means it that the continued Colombian use of natural gas and coal in the long run may only be viable in a best-case scenario for CCUS costs. This suggests that any cost-benefit analysis of slower Colombian transitions which include long-term role for gas should include a conservative estimate of CCUS as part of the costs of a gas-based pathway.

This could tip the balance in favour of greater reliance on electrification and use of hydrogen and hydrogen derivatives and lower reliance on natural gas (and coal) than is currently envisaged in Colombian transition plans. A comprehensive understanding of Colombian CCUS costs should therefore be an urgent priority.

5.2.3.2. AFOLU emissions reduction plan

An assessment of the risks associated with Colombia's plans to reduce emissions from land use (or AFOLU) sectors was outside of the scope of this study. However, the authors noted that the challenges of turning Colombia's largest source of greenhouse gas emissions into a net sink could be more challenging than decarbonisation of the sectors that were in scope for the study. This is due to the heterogeneous nature of the activities contributing to the emissions[343]; the large number of people involved in those activities[344]; the limited risk-bearing capacity and access to capital of many involved; data gaps and long-running disputes relating to land rights[345]; and the physical climate and nature-related risks causing ecosystem degradation[346] that would release more carbon and which are not yet well understood in the Colombian context. We are not aware of any cross-cutting Colombian policy strategy designed to address these issues in the round, including issues relating to agricultural productivity, land rights, labour, access to capital and low economic resilience.

If Colombia falls short of its targets to reduce AFOLU emissions then, to meet the E2050 goal, it will need to accelerate decarbonisation in the sectors reviewed in this report and/or become more reliant on the deployment of CCUS.

In this sense, resolving uncertainty about the deliverability of CCUS and of AFOLU emissions reductions plans would be the most powerful tool for reducing risk and uncertainty for energy and industrial sectors, particularly around the overall speed of transition.

5.2.3.3. Biofuels and biomass

Unlike CCUS, biofuels and biomass are already an important part of the Colombian energy system. As far as technology costs go, it would therefore be a less risky option to base a climate transition strategy on biofuels and biomass, than on fossil fuels and CCUS. If CCUS proves cost effective, a combination of bioenergy and CCUS (or BECCS) could prove an attractive option for Colombia and globally, as BECCS is one of the few "negative emissions" or "carbon drawdown" technologies thought capable of being "net positive" in terms of greenhouse gas emissions[347].

Colombia is today trying to displace the use of solid biomass in residential cooking, while ramping up the use of the fuel in co-firing with coal in cement production. However, the most important use of bioenergy is the bioethanol and biodiesel consumed as transport fuels and produced using domestically grown sugar cane and palm oil. For the sugar and palm oil industries, producing biofuels is a high value-added business, with demand driven by a national biofuel blending mandate, which requires diesel retailers to sell fuel with at least 12% biodiesel[348]. However, while biofuels have been successful in reducing Colombia's transport emissions, government has only recently stated an intention to develop a broader strategy as to how to get the most value out of biofuels[349].

According to the consultancy Energy Transitions Commission[350], on a global basis, biofuels offer one of the few cost-efficient routes for decarbonising medium-to-long haul air travel, being combined with hydrogen to make zero carbon synthetic air fuel (sustainable air fuels or SAFs). As well assessing the potential opportunities for export (as per section 5.3), we assume that the new biofuels strategy will need to tackle the question about the extent to which more land will become available for growing the crops required for biofuels production and will address the question of the relative value – in terms of carbon sequestration – of all the options for that piece of land, including biofuels production for domestic consumption or export, afforestation to reduce domestic emissions or for sale of offsets.

343. In 2019, according to (https://www.worldbank.org/en/news/feature/2019/07/08/trees-and-cows-offer-path-to-recovery-in-colombia), cattle ranching provided 28% of rural employment and livelihoods for 514,000 households
344. Insecure land tenure and access to finance are highlighted in https://s3.amazonaws.com/feldactiontracker.org/green-finance/Shifting+Finance+Colombia+Case+Study.pdf as key drivers of poor productivity and high emissions intensity in Colombia's agricultural sectors
345. There is widespread concern about the potential increase in ecosystem degradation (as has been the case with deforestation – see chapter 2) following the peace agreement in 2016. Sources: https://news.climate.columbia.edu/2018/09/12/colombia-conflict-ecology-biodiversity/ and https://icg-prod.s3.amazonaws.com/091-colombia-broken-canopy.pdf).
346. Source: https://www.iea.org/reports/combining-bioenergy-with-ccs
347. Source: https://www.fas.usda.gov/data/colombia-biofuels-annual-7#:~:text=While%20Colombia's%20government%20decreased%20its,despite%20there%20being%20no%20trade
348. The Energy Transition CONPES calls for the development of a roadmap for biofuels by the end of 2023, including pilots that would allow a shift from first generation to second and third generation biofuels
349. Source: https://www.energy-transitions.org/energy-transitions-commission-warns-demand-for-biomass-likely-to-exceed-sustainable-supply/
350. Hoja de Ruta del Hidrógeno (2022)

Table 55: **Assumptions underpinning Colombian alternative deep decarbonisation scenario**

Sector	Position in 2050 compared with BAU
Steel	Steel demand lower than in BAU (because of greater uptake of circular solutions) but still higher than in 2020. Primary steel produced by H2-DRI process, with BF-BOF process at Paz del Rio decommissioned.
Cement	Cement demand lower than in BAU (because of greater uptake of circular solutions) but still higher than in 2020. CCUS used to capture remaining process emissions. Partial switch from natural gas to hydrogen or electricity for lower temperature heat.
Thermal coal	Coal entirely phased out in power stations and in lower temperature industrial heat applications. Retained in cement production, but only with CCUS.
Met coal and coke	Entirely phased out because of end of primary steelmaking at Paz del Rio and decline of BF-BOF steelmaking process globally. Some coke making plants may continue to operate, but only if industrial users and coke making plants can be fitted with CCUS at a cost comparable with low carbon alternatives.
Diesel	Diesel use in freight and public road transport reduced by 80% compared to BAU, through efficiency gains and ceding market share to FCEVs and BEVs. Use in other industrial applications dependent on viability of low carbon substitutes
Gasoline	Use in passenger LDVs, vans and motorbikes set to drop by 82% due to competition from BEV and FCEVs, as well as modal shift to public transport.
LPG	Not likely to enter the transport fuel market due to competition from more economic low carbon transport solutions
Natural gas	Inefficient gas completely phased out with efficient CCGT only viable as providers of flexibility with abated emissions through CCS or retrofitting to burn hydrogen. Growth in the transport sector limited due to competition from more economic low carbon transport solutions. Uses in industry dependent on hydrogen scale and penetration across Colombia.
Electricity	High levels of electrification across transport and industry – conventional ICE vehicle share in 2050 will drop from 12% to 3% from a domestic BAU scenario to a domestic WB2C scenario.
Hydrogen	According to the Hoja de Ruta[351] , total green and blue Hydrogen consumption could rise to 1,850 kt by 2050, while as much as 1,541 kt is assumed for our domestic WB2C scenario.

Given the challenges of scaling up biofuel production and distribution, Colombia's AFOLU decarbonisation strategy and the potentially additional value the country could realise from exports, electricity- and hydrogen-based deep decarbonisation pathways may be less risky than ones with a much-expanded role for CCUS and/or biofuels. Based on the alternative scenarios described earlier in this chapter for transport, power and, industry, the table set out illustrates such a scenario:

5.2.3.4. Decarbonisation pathways and market design options for industrial sectors

In section 5.5, we review some of the challenges relating to hard-to-abate Colombian industrial sectors and noted how the PEN assumes that deep decarbonisation in Colombian industrial sectors is not possible to the same scale as power and transport decarbonisation. Our research showed that many technological, business model and regulatory framework challenges remain unresolved.

Until detailed power and transportation planning is supplemented by similar planning for industrial sectors, arriving at clear decisions on the cost of new natural gas, hydrogen and CCUS infrastructure will be very

351. Natural gas is typically produced by larger firms and so its producers may be more resilient

difficult. This is because the tariff that network operators will need to charge to recover their investments and earn a risk-adjusted return will partly be driven by the volume being transported through them, which in turn will depend on the speed of industrial decarbonisation. Similarly, upstream, the speed of decarbonisation of each Colombian industry will have a material impact on the climate transition risk exposure of the small firms producing coal and coke[352] for consumption by domestic industry.

In more consolidated industries with the greater presence of international investors, Colombian firms are more likely to benefit from expertise coming from the global transition, including steel production, and cement / concrete. However, less consolidated, more labour-intensive industries with a greater focus on the domestic market – including sugar refining, pulp and paper, brickmaking, glassmaking, and textiles – are more likely to benefit from targeted support to build an understanding of decarbonisation options, their relative costs and potential funding sources. We would recommend that the Colombian government prioritises the development of technoeconomic studies in this second group of industries, which will also help to build a clearer picture of risk-bearing capacity and funding requirements in the sectors.

Through this analysis, it should be possible to get a clearer understanding of the ability of Colombian industry to bear the costs of retrofitting or building new capital expenditure and the extent to which these costs could make them vulnerable to import substitution (for example, in textile or in steel) or material substitution (for example, in paper and in brickmaking). In turn, this analysis can inform decisions about what form (if any) of government support to provide to reduce decarbonisation costs.

For example, in Germany, policymakers have recently set out plans for the widespread use of "carbon contracts for difference[353]" to accelerate investment in decarbonisation of steel, cement, and other industries. Drawing on the massive success of the UK's contracts for difference (CFD) scheme for renewable energy projects[354], which has been successful in driving cost reductions in offshore wind projects, the carbon CFD would provide price certainty for investors in low carbon industrial projects, by paying a fixed top-up to the prevailing market price when the market price is lower than the marginal cost of producing a unit of, say, steel product. By contrast, if market prices rise higher than the marginal cost of producing the unit, the steel producer would have to make a payment in reverse. While the final design in Germany is still evolving, in the UK, the costs of net support payments to offshore wind plants was borne by retail consumers as a fixed levy on electricity bills. For offshore wind investors, the effect was to provide price certainty, which helped to secure higher shares of debt financing, a lower cost of capital, higher deployment, and lower future prices. For industrial sectors where the operating cost of the low carbon fuel is higher than the comparator fossil fuel, a carbon CFD may need to be complemented with fixed volume procurement commitments, perhaps through public procurement or as a requirement for private contractors seeking to secure public-private partnership arrangements in Colombia's ambitious 4G and 5G infrastructure procurement programme.

5.5.3.5. Technological and market design options for flexible "clean firm" power generation

The ability to expand electrification (and green hydrogen) as a decarbonisation solution for Colombian transport and industry will be dependent on Colombia's ability to reach zero or very close to zero emissions in power generation. In turn, the ability to do this will be conditional partly, on the expansion of network and storage infrastructure[355] (see 5.5.3.6 below) and on the ability to use alternative technologies to meet Colombia's reliability / capacity and flexibility needs without using fossil fuelled generation.

Colombia will benefit from investment in R&D and deployment of "clean firm" and "clean flexible" power solutions around the world in addressing common system challenges like ramping, day-night flexibility[356], frequency response[357], inertia[358], and spinning reserve[359]. However, the country faces its own specific challenges arising from its reliance on hydro generation, which has meant significant fluctuations in the available of water year-on-year between La Niña and El Niño cycles and potential increase in the intensity of those cycles as Colombia.

352. Carbon contracts for difference: https://www.csis.org/analysis/germanys-hydrogen-industrial-strategy#:~:text=The%20German%20government%20wants%20to,with%20their%20process%2Drelated%20emissions.
353. Offshore: https://www.carbonbrief.org/analysis-record-low-uk-offshore-wind-cheaper-than-existing-gas-plants-by-2023/
354. Increases in the take-up of distributed generation, such as rooftop solar PV, could reduce the amount of required transmission-connected clean power and the amount of incremental investment required in new network infrastructure.
355. Electricity analysts are increasingly disaggregating the sorts of system services historically provided by fossil fuel power plants, which can provide the basis for systems operators to disaggregate revenue streams and invite competition from other technology providers and demand side response. These issues are set out clearly in https://www.climatepolicyinitiative.org/publication/flexibility-path-low-carbon-low-cost-electricity-grids/
356. Frequency response was one of the first services in the UK where tenders were opened to non-power plants. In the auctions, batteries provided much cheaper bids than alternative technologies. Source: https://www.nationalgrideso.com/industry-information/balancing-services/frequency-response-services
357. National Grid in the UK is one of the leading system operators starting to apply synthetic inertia technologies and business models in practice. Source: https://www.nationalgrideso.com/news/our-new-approach-inertia-and-other-stability-services
358. Research has also shown that spinning reserve can be provided by renewable energy generation, although where there are existing thermal power stations, it may be cheaper to use them to provide these services without generating electricity. Source: https://ietresearch.onlinelibrary.wiley.com/doi/full/10.1049/rpg2.12216
359. Early in the last decade, the Dutch government sought to help to reduce the costs of offshore wind developments but undertaking to complete vital project development work, including wind speed monitoring, seabed surveys etc. which were then provided to bidders in an auction for revenue support. The idea was that this would help reduce development cost and operating risk and hence increase the amount of debt that lenders would be willing to provide for a given project size (i.e. increase the gearing). This would reduce the cost of capital, the levelised cost of the project and hence the amount of revenue support that developers needed to bid for. More information on the Dutch system is set out here: https://www.rvo.nl/sites/default/files/2021/10/Dutch%20Offshore%20Wind%20Guide%202022.pdf.

The requirement for back-up capacity in El Niño years, led to the introduction of the *Cargo de confiabilidad* (the "reliability charge") mechanism in the Colombian power system, after major power shortages in 2000.

The shift from an electricity market reliant on fossil fuel assets and water resources subject to seasonal and inter-annual variability, to one built on the foundation of hydro, wind and solar, reliable generation sources with a mixture of daily and seasonal variability, would fundamentally change the physical characteristics of the Colombian power system. Most other power systems operators around the world have been grappling with a version of this set of issues for over a decade, meaning that Colombia, which has embarked on its power sector decarbonisation journey only very recently, can draw on a lot of experience and analysis. For back-up services, Colombia should consider a range of potential low-carbon technologies including geothermal, biomass, and hydrogen. Natural gas with CCUS is also potentially a provider of low emission back-up generation, although with the cost of CCUS per kilowatt hour likely to be high (because of a small number of load hours over which to amortise the capital expenditure), this would likely be prohibitively expensive.

We recommend that the Colombian government, UPME, and the system operator XM create an open-source access platform for historic data on economic dispatch, transmission constraints, physical generation, and frequency data. This could provide a common basis for current and potential market participants, academics, and civil society to create models of future Colombian power systems with different technology mixes.

This would provide an evidence base to inform a discussion about the benefits of a reformed electricity market design of the sort currently underway in many parts of the world. This could potentially include the gradual phase out of the "reliability option" scheme and its replacement with multiple alternative revenue streams, including those with high revenue certainty to support financing, while real time price signals are retained to incentivise efficient investments in electric vehicle charging, distributed solar PV and green hydrogen production and storage.

5.2.3.6. Infrastructure planning

With uncertainty about the speed of Colombia's energy, transport, and industrial sector transitions; the technologies that will be prioritised in those transition; and the market rules and incentives that will exist in future Colombian markets; planning of capital-intensive infrastructure becomes an extremely difficult challenge. And yet, delays in key enabling infrastructure investments can be one of the main barriers to the timely scale-up of low carbon industries. For example, Colombia's track record of slow expansion of electricity transmission network expansion in the north of the country has cast doubt for some about the ability for electrification to be the main driver of Colombia's deep decarbonisation.

Persistent uncertainty could have a direct impact on the cost of capital in new infrastructure investment, in particular, for new network (electricity, gas, hydrogen, and CO2) and other core infrastructure, such as rail lines and ports, as financiers become more concerned about the risk of future stranding. By contrast, the experience with offshore wind in the Netherlands[360] and new nuclear in the UK[361] has shown that targeted participation by government in some infrastructure project risks can reduce the overall cost of capital and cost to the consumer.

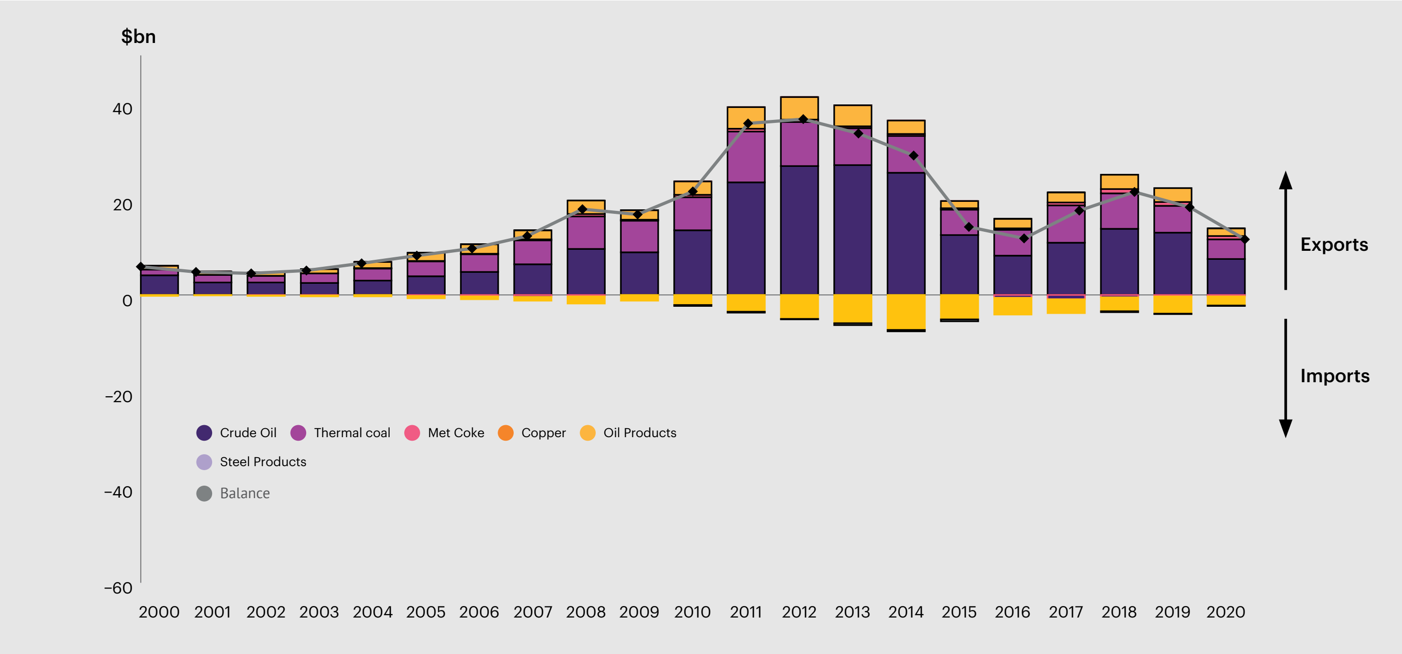
We recommend that, before committing public money or risk capacity to support new electricity network investments, Colombia's network operators, public-private partnership operators and the government stress test the viability of network investments against different external and domestic transition scenarios. This could use the scenarios discussed in sections 5.5.1 and 5.5.2 (or similar alternatives) to reduce asymmetry of information and to build a common understanding and pricing of climate transition risk into Colombia's financing markets.

5.2.3.7. Alternative economic models with less reliance on fossil fuel rents

For those supporting long-term use of coal, oil, and natural gas in Colombia despite the risks highlighted in this paper (in relation both to the external and domestic transition risks), the decline of these industries can only bring economic devastation to Colombia. If Colombia's recent economic history was a meaningful guide to what could happen in a deeply decarbonised future Colombia, it is easy to see how one could come to this conclusion. As illustrated in figure 34, in every year between 2000 and 2020, Colombian generated a net trade surplus in fossil fuel commodities and a net trade deficit in all other goods combinedand 2020, Colombia had a trade surplus in fossil fuels, which served to offset a net trade deficit across all other goods exports and imports.

360. The UK has sought to use regulatory mechanisms to reduce revenue risks for developers of new nuclear power plants, including the use of CfDs. The "regulated asset base mechanism" proposed for Sizewell C would improve develop returns still further, by allowing developers to start to earn revenue during construction. The quid pro quo would be to reduce the amount of revenue support provided by consumers. The proposed government equity stake would further shift the burden from consumers onto taxpayers – though the basis for providing this support. Source: https://www.gov.uk/government/publications/nuclear-regulated-asset-base-rab-model-statement-on-procedure-and-criteria-for-design
361. Like the Marco Fiscal de Mediano Plazo

Figure 34: **Colombia's historic fossil fuel trade balance**



However, according to the analysis in this paper, the long-term continuation of an economic model with based on extraction and redistribution of fossil fuel rents appears close to impossible in a world that decarbonises in line with the Paris agreement, due to the decline in Colombian oil production, the sharp decline in the seaborne coal market that would arise in a global WB2C scenario and the fact that alternative potential new commodity exports (such as copper) are unlikely to generate such rents as crude oil. For as long as Colombia's government and firms continue to make long-lasting capital investments based on the continuation of this economic model, the more material the quantum of climate transition risk.

We would therefore recommend that the government, central bank, Colombian academics, and civil society accelerate research to assess Colombia's potential alternative economic options and to consider the policy choices set out in this section against those potential alternative models. Given the ongoing process to turn the E2050 vision into an implementation plan, combined with the opportunities afforded by a new Plan Nacional de Desarrollo of an incoming government, this could be an opportune moment to think about alternative economic structures as well as sector-specific transition pathways.

5.2.4 Enhance public transparency about the data, scenarios, and detailed policy priorities underpinning Colombia's long-term deep decarbonisation plans

In chapter 4, we reviewed how a combination of Colombia's material exposure to external climate transition risk, plus the potential allocation of more than 40% of that risk to the public balance sheet could put at risk Colombia's sovereign credit rating. If Colombia does not effectively manage its external climate transition risk exposure and faces the consequences described in chapter 4, the increased Colombian cost of capital and consequent increase in inflation could increase the returns required by international investors for supporting Colombia's transition. In this scenario, government's ability to offer guarantees / credit support to infrastructure deals could also be constrained, potentially creating a vicious circle in terms of the ability to attract investment into Colombia at reasonable cost.

As international and domestic investors and influential international financial sector participants, such as credit rating agencies and development finance institutions start to understand the extent to which climate transition risk in Colombia is likely to fall on the sovereign, we would expect them to start to ask for increasingly more detail about the processes that Colombia is putting in place to identify, monitor, measure, and manage climate risks.

Just as it has done when it comes to green finance, and climate related financial regulation, Colombia could benefit from being – and being seen to be – a leader in incorporating climate risk analysis into public financial planning. Once climate risk analysis has been embedded into public planning, Colombia should consider incorporating disclosure about scenario analysis and the public finances into its medium-term budgetary planning documents[362] and in the information provided to rating agencies and potential investors in new bond issuances. In-house disclosure and analysis about climate transition risk and planning will also help Colombia access new sorts of climate-conscious capital referred to in section 5.5.

Either actions may be less aimed at an external audience but could be no less effective in helping Colombia manage risk appropriately, including implementing a process for measuring and monitoring climate-related contingent liabilities[363] (such as those referred to in chapter 4) and introducing mandatory climate transition risk assessments for material investment decisions in major state-owned enterprises. The latter could help to reduce the likelihood that material new investments by state-owned enterprises continue to increase the country's exposure to climate transition risk.

5.2.5 Facilitate an orderly shift of capital flows from sectors expected to face decline in a transition to those expected to be resilient to or benefiting from a transition

Actions and policies designed to reduce Colombia's exposure to climate transition risk, as outlined in this chapter, can help to reduce the cost of Colombia's transition by protecting the country's sovereign credit rating and its position with international investors.

However, while some large, listed firms with investment grade ratings may have relatively stable access to capital market financing[364], the country will also likely need to support other companies and other sectors to increase the flow of investment from both domestic and international sources to meet its targets.

Colombian policymakers can help to reduce the cost of this investment by implementing transparent and predictable policy frameworks and by implementing procurement and regulation rules which allocate risk appropriately to those with risk bearing capacity. This includes the allocation of climate transition risk. For example, if the Colombian government decided to provide increasing financial support to the thermal coal export industry as demand for that product declined, it would represent an expensive an increasing contingent liability. By contrast, in other key industries, such as CCUS, while investors may be willing to take on certain risks around novel technologies (for example, investment in a regulated pipeline network), it may be prohibitively expensive to try to place other risks (for example, around CO2 storage leakage) with private insurers.

Policy transparency around the planned distribution of gains and losses can also help to build broad-based public consent for deep decarbonisation and to maintain the confidence of financial markets through a transition. An orderly transition that encourages the gradual recycling of capital from declining sectors in line with an economy-wide government policy plan consistent with the E2050 vision will be one most likely to avoid collapses in confidence in any one sector. The availability of common and publicly available scenarios with transparent assumptions would assist financial institutions in engaging with their clients about emissions and transition issues and would assist the Superintendencia Financiera in supervising institutions, including monitoring the evolution of climate transition risk at both the microprudential and macroprudential levels and in providing guidance to support the increasing sophistication of financial institution risk management practice in this area.

5.3 Prioritise growth of economic sectors with large-scale export potential

Recent moves to stimulate growth in onshore wind, offshore wind, solar PV, and hydrogen sectors demonstrate the fact that Colombian policymakers value the opportunities associated with Colombia's domestic transition. In some cases, such as wind power in La Guajira, there is even the prospect of new economic activity occurring in a region where legacy industries face decline. However, even where there is not a direct geographical correlation between growth industries and assets/regions facing decline, at a macro level, Colombia would benefit significantly from developing alternative sources of export revenue, increasing volatility in global commodity prices. In a global WB2C scenario, this diversification. With given the expected decline in crude oil and thermal coal exports in a WB2C scenario, promotion of alternative sources of Colombian exports becomes even more urgent

362. Recognition of contingent liabilities – especially climate-related contingent liabilities – by rating agencies is pretty uneven.
363. Of the companies we reviewed, Cementos Argos (cement), Celsia (power), Grupo Energía Bogota (power and gas), Grupo ISA (electricity transmission), Empresas Públicas de Medellín (EPM) and Coltejer (textiles, power) might fit in this category
364. Information about the indices that the analysis support is set out in WTW (2021). WTW analyses for metals not relevant for Colombia, such as lithium and cobalt, is constructed using similar principles to the analysis for copper explained in chapter 2.

Table 56: **Recommendations on diversifying exports**

Prioritise growth of economic sectors with large-scale export potential	
25. Pursue "no regrets" diversification of the Colombian export basket by growing sectors (such as agricultural exports). Consider a range of factors when considering the diversification potential or new or growth economic sectors including potential to scale quickly; potential to bring in foreign currency revenues; potential to diversify the fiscal base; exposure to climate transition risk and physical climate risk	**DNP, ANDI**
26. Design and implement reforms to freight infrastructure, the electricity system and electricity tariffs to ensure a low cost and reliable system that supports Colombia's competitiveness as an exporter of industrial goods	**MME, ANDI**
27. Accelerate diversification of mining exports towards "transition metals", such as copper, subject to thorough assessments of environmental risk. Assess potential investments metal refining / smelting capacity considering climate transition risk.	**MME, ANM, DNP**
28. Conduct research (or join international research efforts) on potential technologies to convert the nickel ores produced in Colombia to battery grade	**MME, DNP**
29. Develop pilot projects relating to the production of synthetic air fuel (SAF) and low carbon marine fuel at Colombian oil refineries	**MME, DNP**
30. Consider the development of a medium-term economy-wide industrial strategy to ensure that Colombia is well prepared to benefit in a deeply decarbonised world	**DNP, MHCP, ANDI**

One area where Colombia has taken significant steps towards developing alternative export sectors is by investigating the potential for diversifying its mining sector towards the field of "transition metals". According to WTW in-house analysis[365] underpinning the STOXX Willis Towers Watson Climate Transition Indices[366], in a WB2C scenario, by 2050, the world could consume 450% more lithium, compared with today; 100% more cobalt; 100% more nickel and 86% more copper. Of these, Colombia currently produces small amounts of copper[367] and is the world's 12th largest producer of nickel. However, our analysis suggests that copper has much greater potential to contribute to Colombia's external balance than nickel.

5.3.1 Non-extractive sectors

The new government has highlighted several of potential areas which can be used to diversify Colombia's reliance on fossil fuels in the export basket, including agricultural products and services. An assessment of these issues was outside the scope of this study.

Colombia's competitiveness as an exporter of goods has historically been hampered by high internal logistics costs and relatively high electricity prices. A domestic transition plan which minimises long-run electricity and hydrogen costs could also help improve Colombia's competitiveness as an exporter of these products, and potentially of other manufactured products.

However, while agricultural and manufacturing exports may help to alleviate pressure on the value of the peso from volatility in Colombia's major export markets, they are less likely to have concomitant benefits for diversifying the fiscal base. This is because most agricultural and manufacturing markets do not attract the same sorts of economic rents that Colombia earns from primary commodity extraction. Unless and until Colombia develops an economic model that is less dependent on resource rents, economic policymakers may see the replacement of one set of extractive industry revenues (in coal and oil) with another set (in transition metals) as the only option to prevent economic destabilisation.

365. See WTW (2021)
366. According to https://mineriaencolombia.anm.gov.co/sites/default/files/2021-08/Colombia%20Diversidad%20Minera%20Agosto%2031%2C%202021_compressed.pdf, Colombia has produced just under 10,000 tonnes per year in recent years, compared with Chile, the largest producer in the world, which produced 5.7 million tonnes in 2022, according to: https://icsg.org/wp-content/uploads/2021/11/ICSG-Factbook-2021.pdf
367. See previous footnote

5.3.2 Copper

Copper is thought to be one of the key commodities crucial for delivering the most likely transition pathways for a global transition to a low carbon future. Due to its unmatched technical characteristics in thermal and electrical conductivity, copper is widely used across a broad range of economics segments and is often difficult to substitute. As well as being one of the most widely used metals today, key applications for copper in the global low carbon transition include its use in low carbon power generation (wind, solar and nuclear), electricity transmission infrastructure and battery technologies (including EVs).

Though Colombia currently produces less than 10,000 tonnes of copper per year as a by-product to the gold mining process, the country has long been thought to have potential to be a much larger producer, given that areas of the north west of the country share many of the same geological characteristics as areas in Chile and Peru where the world's largest copper mines have been developed.

During the Duque administration (2018-2022), Colombia invested significant resources in developing the regulatory framework to support enhanced investment in the extraction of copper, with six Strategic Mining Areas were created across Cesar and La Guajira for exploration in addition to a series of other mining licences granted in the years prior to this[369].

As we set out in the sections below, copper exports are a clear potential growth opportunity for Colombian, which would be more lucrative in a global WB2C scenario than a BAU one. However, the magnitude of the opportunity is significantly less than the downside from crude oil and thermal coal exports and the timing of the upside is likely to occur later than much of the decline in crude oil and thermal coal exports.

368. See: https://mineriaencolombia.anm.gov.co/contenido/areas-estrategicas-mineras#:~:text=Las%20%C3%81reas%20de%20Reserva%20Estrat%C3%A9gica,ser%20otorgadas%20en%20contrato%20de
369.

5.3.2.1. Global climate transition scenarios for copper

In fact, given that the current identified global supply of copper so far falls short of global demand by the mid-2020s, we can say with reasonable confidence that substantially all Colombian copper that is extracted and available for export would be competitive on the global market.

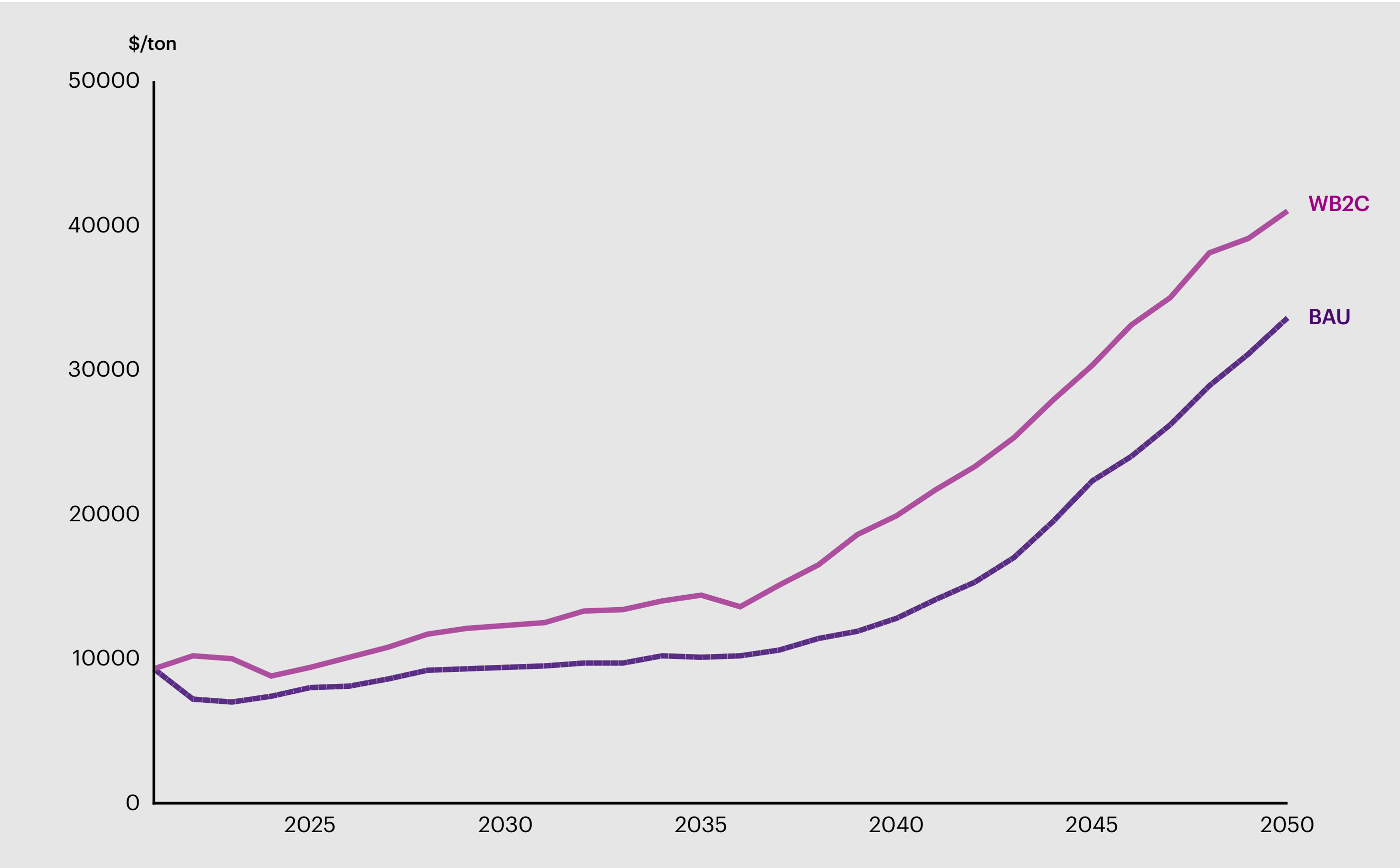
Using in-house WTW analysis of the impact of a global transition on the value of existing and future (discovered) copper mines, we projected future prices for refined copper in a BAU and WB2C scenario[370]. As with coal, oil, and gas, BAU and WB2C scenarios for copper show different profiles for global copper demand, showing that global demand in a WB2C scenario would accelerate faster than in a BAU scenario.

Higher demand would translate into higher prices in a WB2C scenario (as illustrated in figure 35), at a level sufficient to incentivise new investment not only in extraction, but in exploration.

Table 57: **Refined copper demand scenarios (global)**

		2019	2025	2030	2035	2040	2050
BAU	kt	24,343	28,873	33,679	35,581	37,483	44,160
WB2C	kt	24,343	30,235	36,198	40,051	43,904	48,723

Figure 35: **Copper prices (LME)**



370. As described in Chapter 2, the model used to project future refined copper prices is a Python-based marginal pricing model using CRU as the primary source of supply data. Demand scenarios created bottom up from in-house WTW research considering technological pathways characteristic of each overarching climate transition scenario and their relative copper intensity.

5.3.2.2. Prospects for a Colombian copper industry in a low carbon transition

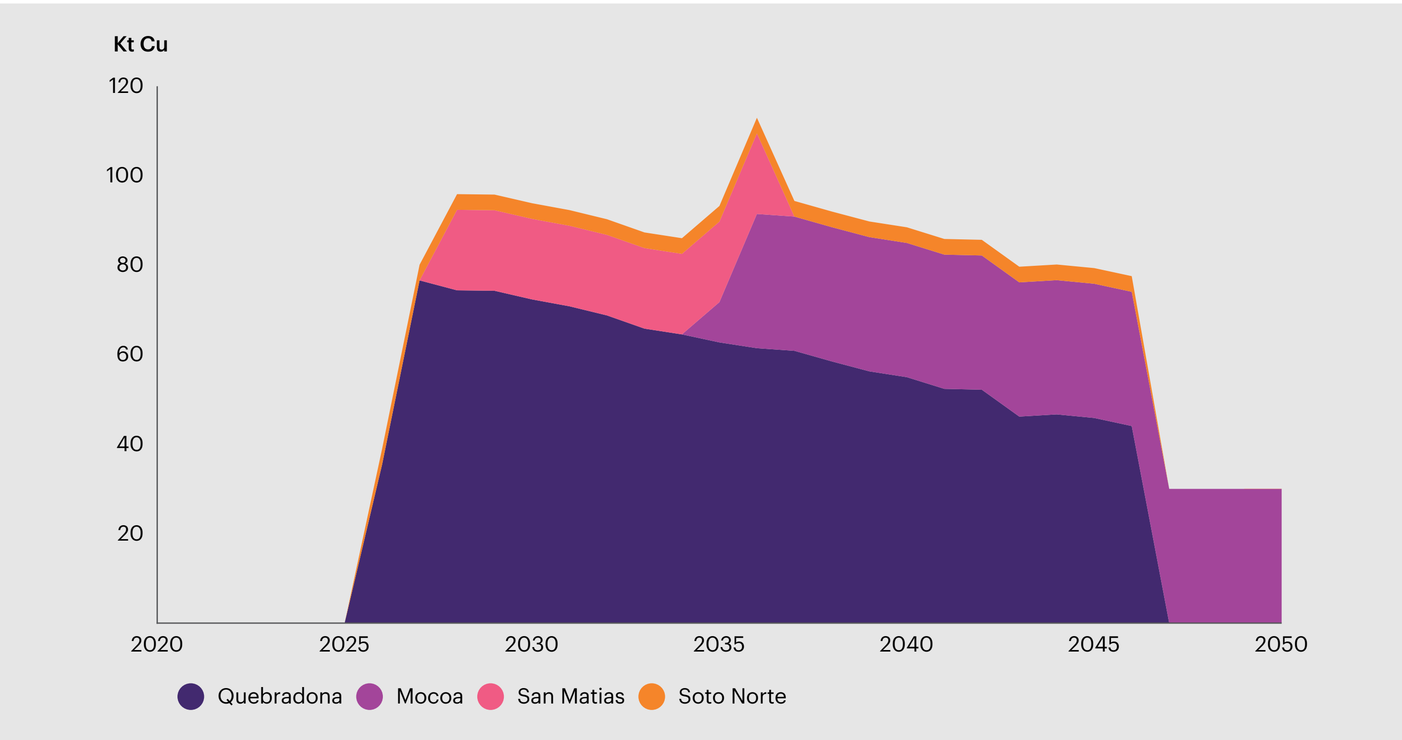
No investments have yet progressed to construction for Colombian mines with copper as the main product, with many prospects facing challenges to obtain all appropriate licences and permissions[371]. Given these challenges, mining analysts at the consultancy CRU believe that the earliest point at which significant production could flow in Colombia would be the late 2020s.

Symptomatic of these challenges is the Antioquia-based Quebradona, which CRU shows as by far the largest of the four most advanced projects. In May 2022, Colombia's environmental regulator, ANLA, rejected an appeal by the prospect's owner, AngloGold Ashanti, relating to the asset's Environmental Impact Assessment (EIA)[372]. If the project goes ahead, Quebradona, along with three other projects recognised by CRU (Mocoa in Putomayo, San Matias in Cordoba and copper by-products from the Soto Norte gold mine in Santander) could result in production peaking at more than 100,000 tonnes of raw copper per year, or more than 10 times Colombia's current annual copper demand. If significant additional economically recoverable production is possible from the new six Strategic Mining Areas, this could transform Colombia into a sizeable player on the global stage, although still small compared with Chile and Peru who between them produced nearly 8 million tonnes in 2020[373].

Our analysis showed that all four of the projects covered in the below figure would be economic in both BAU and WB2C scenarios. However, the prospects for realising that value are complicated by Colombia's current lack of metal refining capacity. Unless Colombia decides to develop copper refining capacity, it would need to export copper concentrate to a country with spare refining capacity, losing an important part of the value add[375.] We estimated the cost of building a copper smelter in Colombia and compared the results for home refining compared with exporting the copper concentrate for refining in China, the country which accounted for over 50% of global smelting capacity in 2020.

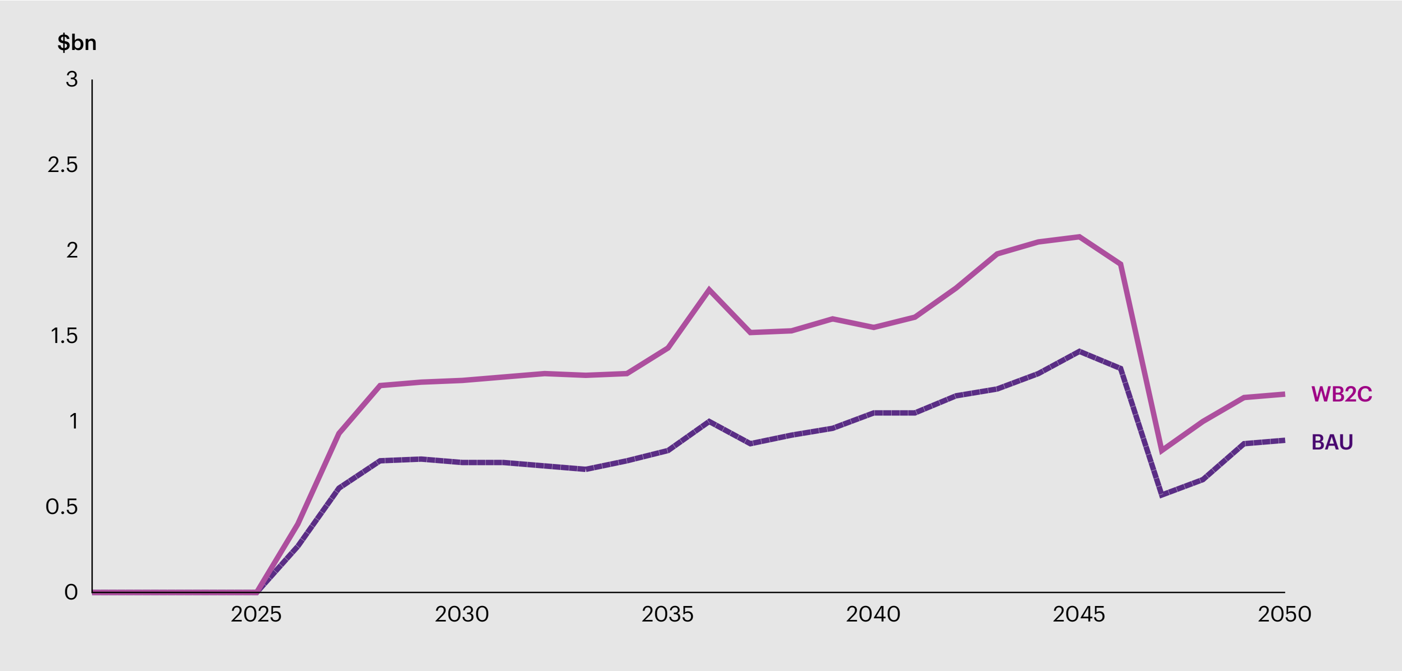
According to that analysis, Colombian copper miners seeking to maximise profits may prefer to ship their copper concentrate to China, if there was spare capacity in Chinese refineries, given that a new Colombian smelter would need to charge higher prices to cover its capital costs (and despite the cost of shipping concentrate to China). However, it seems reasonable to assume that spare capacity in the world's copper refineries will dry up as global demand for copper rises, most likely making a newbuild Colombian refinery competitive to support any significant copper industry.

Figure 36: **Copper production profile by future asset (CRU)**[374]



371. See: https://www.business-humanrights.org/en/latest-news/no-respuesta-de-libero-copper-gold-sobre-presunto-incumplimiento-a-acuerdo-de-una-entidad-pol%C3%ADtico-administrativa-que-proh%C3%ADbe-la-miner%C3%ADa-en-mocoa/
372. See: https://www.business-humanrights.org/en/latest-news/colombia-national-environmental-licensing-agency-rejects-anglogolds-appeal-on-quebradona-project-licence/
373. Source: International Copper Study Group (2021)
374. These are CRU and WTW assessments of economically recoverable reserves, rather than technical reserves outlined by the producers
375. On average, we estimate that refining costs represent around 10% of total delivered prices for refined copper

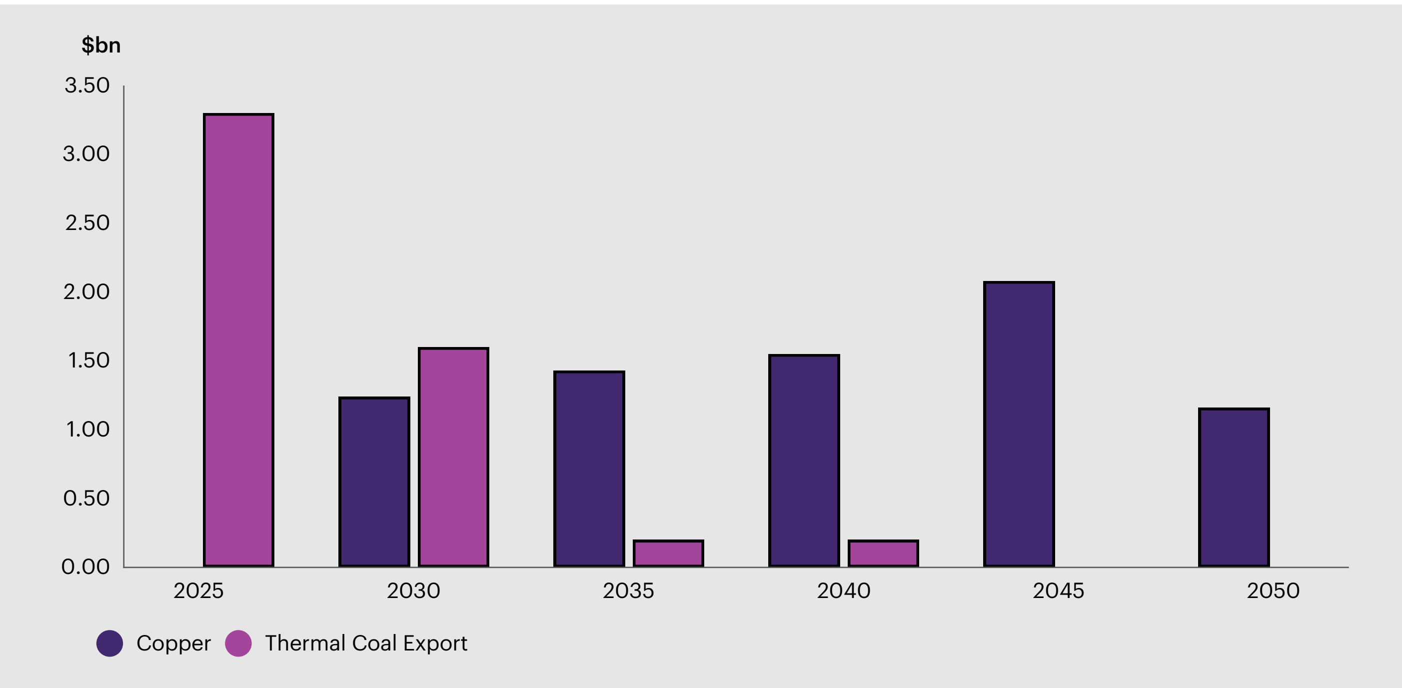
Figure 37: **Copper revenues scenario (BAU vs. WB2C)**



With refining charges representing approximately 10% of refined copper prices, Colombia's peak annual copper revenues could top $1 billion per annum in a BAU scenario, as set out in figure 38 below. In a WB2C scenario, where Colombian copper would earn higher prices, peak revenues would be higher, at $2 billion per annum. We calculated the different the net present value of the difference in value to Colombia between WB2C and BAU scenarios at $3.8 billion.

At these levels (which could be exceeded if there is success in the Strategic Mining Areas), Colombian copper export revenues would – in the long run - partially offset the decline in revenues from coal mining. However, the timing of these revenues is likely to be later than the WB2C decline in thermal coal exports explored in Chapter 3.

Figure 38: **Copper vs. coal revenues**



The size of this potential industry is more uncertain than the timing. If Colombia were only to develop the four assets that we have modelled and referred to above, the revenues would also be insufficient to offset the projected decline in crude oil exports, meaning that Colombia would still be likely to face a structural challenge around its external balance (as well as its national and local public finances). However, if Colombia's as-yet-unexplored areas prove to have similar deposits to those in Chile and Peru that may form part of the same geological seam, the potential yields could be significantly higher in the long term than the numbers presented here.

5.3.3 Nickel

Like copper, nickel is another "transition metal" for whom demand is expected to boom in a global energy transition, mainly due to the key role it plays as a cathode in lithium-ion batteries[376]. As WTW's in-house nickel analysis is still in development, we have conducted a qualitative review of a range of third-party sources for estimates of the supply/demand/price implications of a global low carbon transition.

Based on this research, we concluded that demand for nickel will likely be higher in a WB2C scenario than in a BAU one, leading to generally to transition upside. However, the dynamics for different types of nickel ores appear very different. In short run, mines that currently produce "ferronickels" (nickel-iron alloys that are used to produce stainless steel) would likely be able to benefit from a gradual increase in global steel demand, as explored in chapter 3. However, they are currently unlikely to be able to benefit from the much sharper increase in demand for high grade "class-1" nickel required for use in batteries as no commercial technologies are currently available to perform the process[377].

Colombia's Cerro Matoso mine (owned by international mining major South32) is globally significant in the context of today's nickel market, which is dominated by its use in steel production. Colombia exported more than $400 million of ferroalloys in 2020 or approximately one tenth of the value of its thermal coal exports in that year [378]. However, we understand that the type of ore mined at Cerro Matoso (saprolitic laterite) is one that cannot be used or converted for use in lithium-ion batteries[379]. Without significant prospects for expanding nickel mining capacity, Colombia's prospects for transition upside in nickel will likely be limited to slightly higher prices for Cerro Matoso's output in a WB2C scenario.

5.3.4 Hydrogen, synthetic aviation fuel, and low carbon shipping fuels

While "transition metals" are critically important building blocks for many of the enabling technologies for a strategy of deep decarbonisation based on clean electricity grids, in recent years, significant increases in R&D spend have been directed towards sectors seen to be "hard-to-abate" and particularly in applications where electricity is seen as less promising. These include most industrial sectors, plus shipping, freight, and air transport.

Many potential solutions to these challenging decarbonisation questions involve hydrogen, bioenergy, or combinations of the two. Colombia has previously identified that it may have a competitive advantage as a potential exporter of bioenergy-related products[380] (and other land products), while the existence of a well-established ethanol production industry could make Colombia well placed to scale-up production to produce sustainable aviation fuels (SAFs), using the "alcohol-to-jet" process. However, Colombian policymakers should also factor into this calculation the international trend towards second and third "generation" biofuels, produced from sources (such as cooking oil, waste) that do not require competition for land. This may mean that SAFs produced from ethanol become only a temporary export opportunity, and that biomass and biofuel production may – in the long run - be best used as part of Colombia's domestic transition.

By contrast, hydrogen may have much greater potential for Colombia as its supply is not limited by land constraints. Hydrogen can be a driver of decarbonisation in Colombia across sectors (see section 5.3 and section 5.4), but as a component of certain emerging synthetic jet fuel technologies, low carbon ammonia and methanol, it could be the core of a new export industry with sustainable growth potential. Colombia may have a competitive advantage here as a potentially very low-cost producer of green hydrogen[381]. The country's proximity to the Panama Canal may also give it an advantage compared with other exporters. Of multiple potential low carbon shipping fuel technologies, the ones that currently seem the most promising are the ones made using e-ammonia or e-methanol, themselves made using green or blue hydrogen as a major component.

376. For a description of supply and demand dynamics for nickel, see: https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf
377. A new "high pressure leaching" technology is being trialled in Indonesia, although Indonesian ores have different chemistries to the ones in Colombia. See: https://www.spglobal.com/marketintelligence/en/news-insights/blog/profit-margins-key-to-tsingshans-battery-nickel-supply-plans for more details on this technology
378. Source – MIT OEC
379. South32 sets out a strategy for Cerro Matoso here: https://www.south32.net/docs/default-source/exchange-releases/strategy-and-business-update.pdf?sfvrsn=6990eb4f_4. This strategy appears to remain focused on ferronickel, with no reference here to potential upside and sales to battery manufacturers
380. This is identified explicitly in the Energy Transition CONPES
381. According to the MinMinas (2021), green hydrogen production costs in the north of the country could fall as low as $1.5/kg by the 2030s, making Colombian hydrogen competitive with Chile.

Colombia has the potential to become a major exporter of low carbon shipping fuel, though e-ammonia and e-methanol could also be valuable products in their own right, either as export products or as components of domestic industry replacing ammonia and methanol produced from natural gas and helping to reduce imports of those products as well as products made using ammonia and methanol as key components, including nitrogen fertiliser and more complex chemicals.

Colombia should prioritise the development of these potential industries, building from pilots both internationally and in Colombia, to develop an assessment of the potential value that the sectors can create and over which timeframes.

5.4 Using the domestic transition to offset external transition risk

Given that alternative exports seem unlikely to offset natural production decline and external transition risk in crude oil and thermal coal, Colombian policymakers ought to take additional actions to mitigate these potentially destabilising risks. One way to do this is via the actions the country takes as it pursues deep decarbonisation in line with the vision set out in the E2050. Of the multiple technological paths the country could take in decarbonising power, transport, industrial, and agricultural industries, some are better suited to mitigating external transition risks than others.

Within the planning for Colombia's low carbon transition, some items are included in all pathways – such as a decline in the market share of coal power and the elimination of greenhouse gas emissions from deforestation – while many other options remain. The Energy Transition CONPES lists a wide range of additional studies, roadmaps and investigations to be completed before 2030, with significant further investments being planned across natural gas, onshore wind, offshore wind, solar PV, biofuels, green and blue hydrogen, carbon capture, and related network and other infrastructure. Colombia's new government appears to have narrowed the range of options by ruling out fracking and placing doubt on the likelihood of new oil and gas exploration. Public debate over the merits and ethics of slower or faster transitions have intensified amid concerns that a faster transition away from oil and gas production could result in significant economic costs.

The team explored the risks and costs associated with faster and slower Colombian transitions, in line with the alternative domestic transition scenario explained in chapter 2 and represented as table 58 below.

Table 58: **WB2C scenario (units are millions of tonnes of CO2 equivalent)**

	2014	2020	2030	2040	2050
Baseline	73	62	78	77	72
E2050	73	62	64	35	12
WB2C scenario					
Electricity generation	12	7	7	1	0
Transport	29	29	34	19	8
Coke production	9	10	10	5	0
Other industry (energy usage)	16	10	12	9	2
Residential and commercial	7	6	6	4	2
Total – PEN scope	**73**	**62**	**69**	**38**	**14**
Fugitive emissions	7	5	1	0	0
Industrial process emissions	8	5	7	6	1
Total – all mining, energy, and industrial emissions	**88**	**72**	**77**	**44**	**15**

We concluded that a faster transition away from fossil fuel consumption domestically can help to mitigate external transition risks by reducing future imports of oil, oil products and natural gas. This could be achieved via an accelerated decarbonisation of transport and industry, relative to the scenarios set out in the PEN. Such accelerated decarbonisation would also need to be supported by sufficient and timely investment in renewable energy generation, hydrogen production and related infrastructure.

Relative to our domestic baseline, lower use of liquid fuels in transport, combined with lower use of natural gas in power, transport and industry, could significantly improve the trade balance, which faces decline from the decline in oil production and the external transition-induced decline in coal and coke exports.

Between 2022 and 2050, in a global and domestic WB2C scenario, Colombia would save $22 billion in oil-related net imports, compared with the domestic baseline.

In the context of material external transition risk over which Colombia has limited control, the researchers concluded that a slower, ostensibly more cautious domestic transition may be riskier than a faster one. By reducing reliance on natural gas relative to current plans, this pathway would also reduce Colombia's reliance on carbon capture and storage (CCUS) as a key technology enabler of its E2050 vision.

Tables 59 and 60: **Impact of the domestic transition on the oil and oil products trade balance**

Global WB2C scenario and domestic baseline

		2019	2025	2030	2035	2040	2050
WB2C crude net exports	$ bn	12.7	3.0	-0.4	-3.0	-5.2	-9.9
WB2C product net exports	$ bn	-0.7	0.3	0.2	0.0	0.4	1.4
WB2C balance	**$ bn**	**12.0**	**3.3**	**-0.2**	**-3.0**	**-4.8**	**-8.5**

Global WB2C scenario and domestic WB2C scenario

		2019	2025	2030	2035	2040	2050
Crude net exports	$ bn	12.7	3.0	-0.4	-3.0	-5.2	-9.9
Product net exports	$ bn	-0.7	0.7	1.3	2.3	3.7	6.4
WB2C balance	**$ bn**	**12.0**	**3.7**	**0.9**	**-0.7**	**-1.5**	**-3.5**

Adopt domestic transition policies that support the offsetting of external transition risk	
31. Consider the potential for using transition upsides (for example, in jobs, profits and taxes) to offset transition downsides – in both location and timing	**DNP, MME**
32. Consider and cost alternative accelerated transport decarbonisation scenarios, incorporating the benefits to Colombia from the reduction of future oil and liquid fuel imports	**MinTransporte, DNP, MHCP**
33. Consider and cost alternative accelerated power generation and industrial decarbonisation, incorporating the benefits to Colombia from the reduction of future natural gas imports	**MME, DNP, MHCP**
34. Prioritise modal shifts in both passenger and freight transport to reduce total energy demand in the transport sector	**MinTransporte, MHCP, local governments**
35. Integrating external considerations into decisions around domestic pathways (in particular, around the role of hydrogen), considering the possibilities for domestic demand to incubate export-calibre industries	**DNP**
36. Co-ordinated planning across government, industry, finance, and civil society can help to ensure that infrastructure constraints and inter-sectoral trade-offs are appropriately incorporated into planning	**DNP, MHCP,**

5.4.1 Accelerating the decarbonisation of Colombian transport

In Colombia, decarbonisations in the transport system have historically been principally about reducing air pollution and congestion in urban areas[382], but with the lack of a comprehensive rail system largely limiting opportunities for shifting passenger and freight traffic off the roads, growth in greenhouse emissions from transport has been highly correlated with economic growth. Successful deep decarbonisation of the transport system, will, at the least, mean breaking that correlation. Decarbonising transport is a critical component of Colombia's plans[383] for deep decarbonisation since the sector has become the largest source of Colombian greenhouse gas emissions after land use. Doing so would also result in a long-term decline in the use of oil and gas in the sector.

To assess the potential for accelerated transport decarbonisation, we built alternative transport scenarios from stock forecasts for cars, vans and buses, motorcycles as well as light and heavy trucks (set out in figures 39 and 40). To do this, we used recent Colombia-focused research including a recent third-party consultant report for UPME on deep decarbonisation in Colombian transport[384] and the UniAndes-led project, *Giro Zero*[385], that developed pathways for deep decarbonisation in freight transport. We combined the stock forecasts with third-party estimates of fuel efficiency and Colombian transport practice (number of km per vehicle per year) and fuel prices calculated as part of this project for liquid fuels, natural gas, electricity, and hydrogen. This allowed us to assess total system fuel consumption and cost per year in each scenario.

Underpinning these forecasts are three primary trends: a) modal shift, in freight from road to rail transport and in passenger transport, from private to public transport (although expected to be limited in the short run); b) efficiency gains in road freight logistics; and c) technological substitution.

Figure 40: **Stock forecasts for road freight transport**

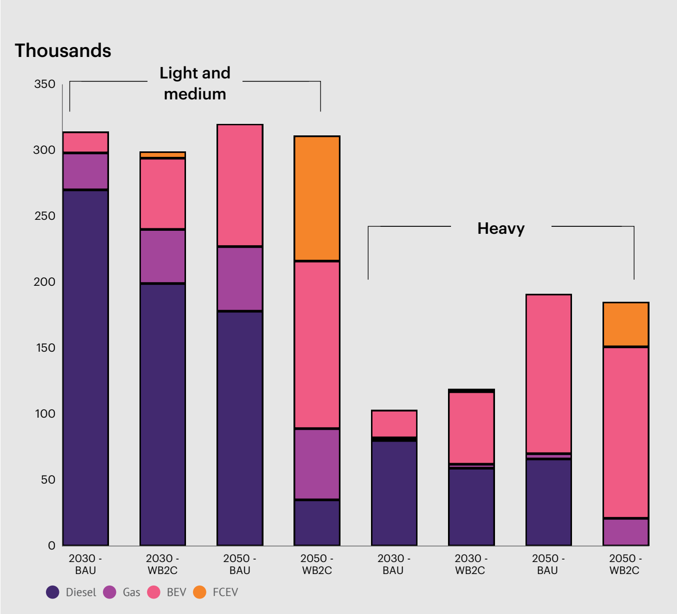
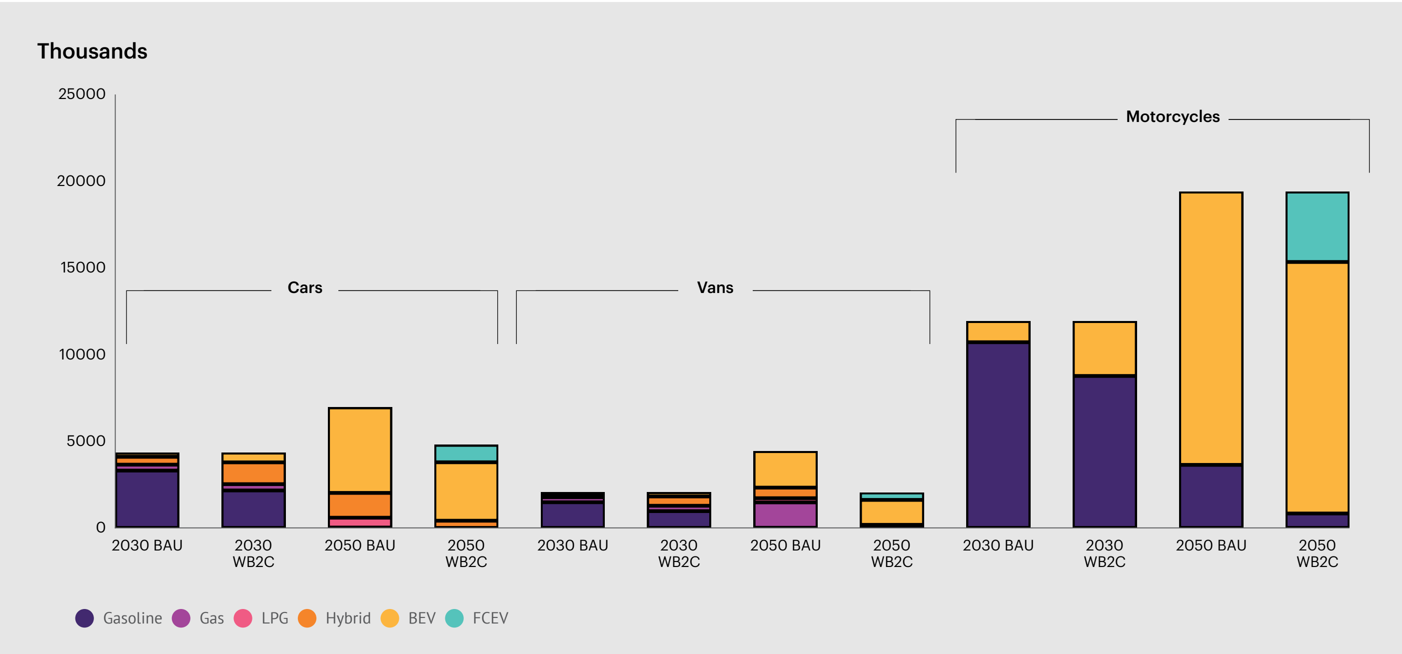


Figure 39: **Stock forecasts for private road transport**



382. Source: https://oxfordbusinessgroup.com/analysis/cities-are-seeking-combat-congestion-and-pollution-through-digitalisation-and-green-public-transport
383. The PEN assumes a change in fuel mix in the transport sector in all its scenarios. Compared with 2019's breakdown of 94% liquid fuels and 6% gas, Colombia's transport sector in 2050 would be powered by 91% liquid fuels, 6% gas and 3% electricity in the most conservative Actualización scenario and 61% liquid fuels, 16% gas, 14% electricity and 9% hydrogen in the most ambitious Disrupción scenario. This does not seem consistent with the E2050 view and the scenarios set out in Steer Group (2020) show much faster decarbonisation
384. See Steer Group (2020).
385. The first report from the Giro Zero project is available here: https://girozero.uniandes.edu.co/system/files/2022-08/docs/GiroZero_Road%20Map_AGO.pdf

5.4.1.1. Passenger transport

For passenger transport, the biggest driver of incremental decarbonisation in our scenario (relative to current Colombian plans) is technological substitution. This is despite the potentially transformational impact of recent public transport projects such as the Transmilenio electric bus fleet and the Bogota metro. Improving the availability and quality of public transport, as well as initiatives to increase the take-up of cycling[386] can significantly contribute to the reduction of liquid fuel consumption in urban environments. However, the logistical and financing challenges[387] can mean that these projects take a long while to come to fruition. Increased public transport could help Colombia decarbonise faster than our scenario or else reduce the among of required investment in private vehicles, electricity generation and electricity networks[388].

According to the current government plan, natural gas, hybrids and electric vehicles basically cover the increase in the stock of cars and vans in the rest of this decade, with hybrids and electric vehicles continuing to dominate in the replacement of gasoline cars over the long-run. In this scenario, gasoline vehicles are mostly phased out by 2050. Growth in electric motorcycles starts later, but all new motorcycles are electric by 2040. In our alternative faster transport decarbonisation scenario, gasoline cars are mostly phased out by 2040 (as opposed to 2050 in the BAU scenario), while hydrogen vehicles take some of the market share from LPG and hybrid vehicles[389].

The uptake of new passenger vehicles in Colombia is currently highly dependent on the upfront cost of vehicle purchase. This, plus the relatively limited ability of charging stations[390], means that gasoline-fuelled cars dominate the market today. However, for those that do own electric vehicles (or hybrids), the annual cost of ownership for a light duty vehicle is already significantly lower than for a gasoline- or natural gas fuelled vehicle. This is both the result of additional efficiency of electric vehicles compared with internal combustion engines, as well as the fact that electric vehicles face a lower tax and duty burden. In addition to these savings, road users would also likely earn significant benefits through lower operating costs and maintenance, though we have not attempted to quantify this here.

The relative savings in running costs to be made by driving an EV compared with a gasoline vehicle are only likely to improve in the short term, given the elevated outlook for global oil prices and plans to unwind the FEPC stabilisation fund, may smooth out the decline for retail gasoline and diesel prices even when global prices fall.

However, the (currently) higher capital cost of electric vehicles means that running costs differentials are not likely to be sufficient to drive large scale technological switching of the sort required to meet even current domestic plans. This means that the feasibility of meeting either scenario may be dependent on an enhanced mix of capital subsidy and/or cheap/innovative financing help to bridge the gap[391].

By the same logic, increasing the rate of carbon tax on liquid fuels may be less likely to encourage significant increases in uptake of hybrids and electric vehicles than more indirect economic incentives, such as waiving eligibility for congestion charges or Bogota's restriction on how many days you can drive your car in the city[392] or non-economic incentives, such as access to priority lanes.

Table 62: **Relative prices of gasoline, gas, electricity, and hydrogen for an LDV - today**

	Gasoline	Gas	BEV	FCEV
Fuel price	\$0.04 per km	\$0.03 per km	\$0.01 per km	\$0.11 per km
Annual travel	148,874 Mkm	720 Mkm	542 Mkm	-
Annual fuel cost	**\$4,559m**	**\$20m**	**\$6m**	**-**

386. See: https://www.c40.org/case-studies/upgrade-of-the-cycle-network-in-bogota-dramatically-increases-bike-trips/
387. See: https://www.oxfordurbanists.com/magazine/2019/4/4/transit-electrification-in-colombia-an-unaffordable-dream for a discussion of some of the practical and financing challenges for designing in electrification of new public transport in the short term.
388. This is because greater penetration of public transport will reduce the number of kilometres travelled per person per year.
389. By comparison, the EU is planning a 100% phase-out of petrol and diesel cars and vans by 2035. Source: https://europeanclimate.org/stories/landmark-victory-on-europes-transport-decarbonisation/
390. Bogotá was due to have 20 rapid charging stations by mid-2022 – a number that has grown quickly but needs to continue to grow much faster to meet transport decarbonisation targets. See: https://climateactiontracker.org/blog/decarbonising-colombias-transport-sector/#:~:text=Or%3A%20Did%20Colombia's%20EV%20law,mandated%20charging%20stations%20to%2040.
391. Lease financing appears to be growing in popularity for electric vehicles in Colombia (source: https://techcrunch.com/2022/03/29/migrante-steps-on-the-gas-of-vehicle-leasing-startup-for-gig-workers-in-latin-america/?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAACtDtoHgzdn3PsWD9eEwIWNxsZMCAW0pSomqcZc0h7otkIyivwE91D3NvIBr6RRzLT29qsZ-Rb8TKmbA9-H3YDI7U4UqwmeOSGoV36Pakog1wI2Eh7aR8MqHvJB1SwcTWfkW2oasdCDhCJCYK2robQ1DP0UXgc6VEoxjZAGV7bTt) while the financial industry was starting to take the transport transition serious as an example (https://latamobility.com/en/financial-solutions-key-to-electromobility/)
392. See: https://kreab.com/bogota/en/insight/new-pot-and-peak-and-plate-restriction-for-bogota/ for a summary of Bogota transport restrictions. London's Ultra Low Emissions Zone has had striking success in reducing air pollution and car use (see: https://www.london.gov.uk/press-releases/mayoral/ulez-reduces-polluting-cars-by-13500-every-day)

5.4.1.2. Freight transport

Freight transport in Colombia may be a harder-to-abate sector in Colombia than private transport, with a small share of diesel vehicles remaining in the stack until 2050 in our alternative faster transport decarbonisation scenario. This reflects the fact that while truck-based freight remains the lifeblood of the country's trade and distribution of resources, ownership of truck fleets is highly dispersed, leading to many of the same problems with access to capital and financing as with private transport. Practical considerations, such as the availability of electric charging stations, charging times and the relatively heavy weight of batteries, may all put a brake on the growth of market share of electric operations in freight transport. Less heavy, more energy dense options, like hydrogen fuel cells, may be practical alternative decarbonisation technologies for road freight, although what operators gain from less weight in a FCEV, they may lose in efficiency, due to losses incurred in converting the hydrogen to electricity in the fuel cell.

Another material factor is the thin margins that many freight operators live with[393]. With internal transport and logistics infrastructure commonly cited as one of the main causes weakening the competitiveness of Colombian industries, freight operators have extremely limited ability either to bear or to pass through increased costs. However, the very thinness of current freight margins suggests that the promise of operating cost savings would likely drive significant switching if the appropriate capital financing and incentives were in place.

5.4.1.3. Mitigating external transition risk via transport sector decarbonisation

Faster decarbonisation in our alternative scenario would result in significant fuel cost savings for Colombia, compared with the government's current plan. We calculated the NPV of total fuel cost savings across the stack, between 2022 and 2050 at **$29.5 billion**, split between **$22.3 billion** for passenger vehicles and **$7.2 billion** for freight. The chart below shows how these figures are compiled, showing significant savings from lower diesel and gasoline use but a higher amount of spent on electricity and hydrogen.

Lower transport system costs would create a gain for the country, which would naturally accrue to fuel consumers (private and business). This could potentially be captured to help fund other transition initiatives (see section 5.4). However, lower fuel costs would also have positive long-run benefits for the trade balance, as explored in figure 42.

To access these potential benefits in a timely manner, investment will need to be front loaded in the near term. Increased penetration of BEVs and FCEVs across road transport will only be possible through investments in charging infrastructure and hydrogen infrastructure, as well as capital incentives to allow lower income groups and smaller freight companies the ability to afford more expensive (in terms of initial capital outlay) BEV and FCEV vehicles. Faster decarbonisation would require more upfront investment, earlier, than in the government's current plan. However, the cost of this investment (likely split between a mix of public and private balance sheets) can partly be reduced via accessing sustainability-linked sources of finance (see section 5.4) and through careful allocation of risks in the new regulatory framework (see section 5.5). Set against this are the benefits of lower fuel costs on consuming spending power which would provide an economic boost, as well as the positive impact on the external balance over the long run, partially mitigating a material source of external transition risk.

393. See Giro Zero (2022)

Figure 41: **Fuel cost savings from an accelerated transport transition (WB2C vs. BAU, NPV). Left: LDVs. Right: Freight.**

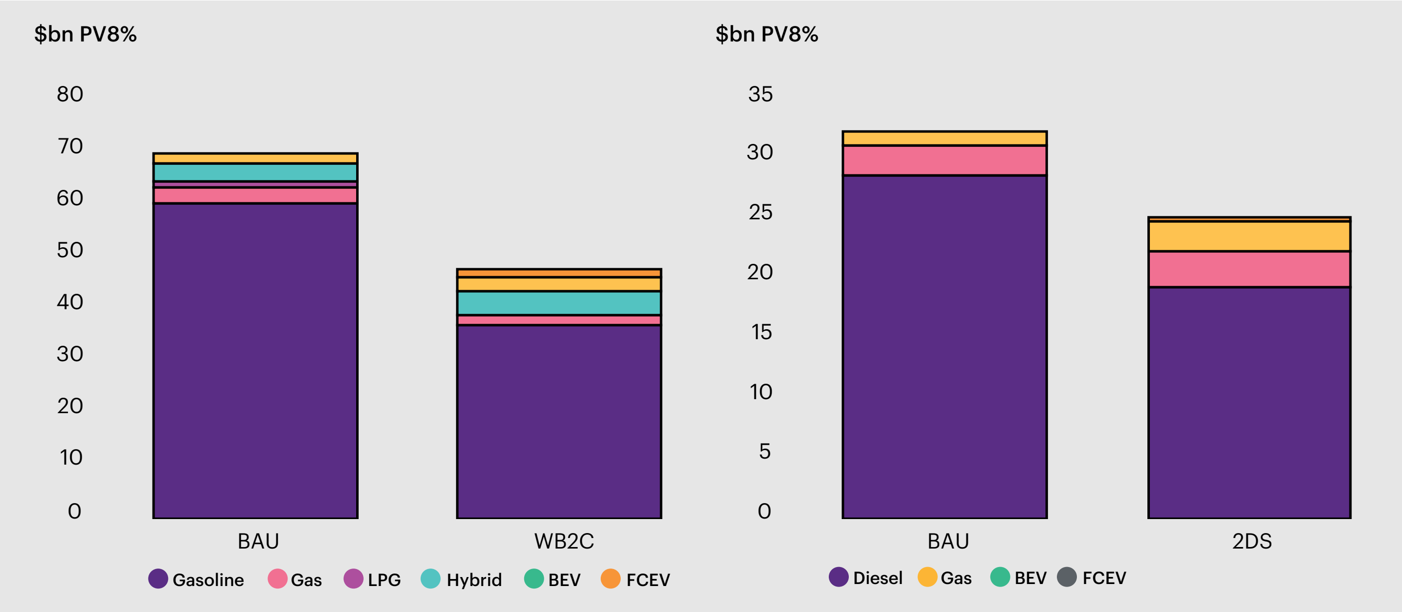
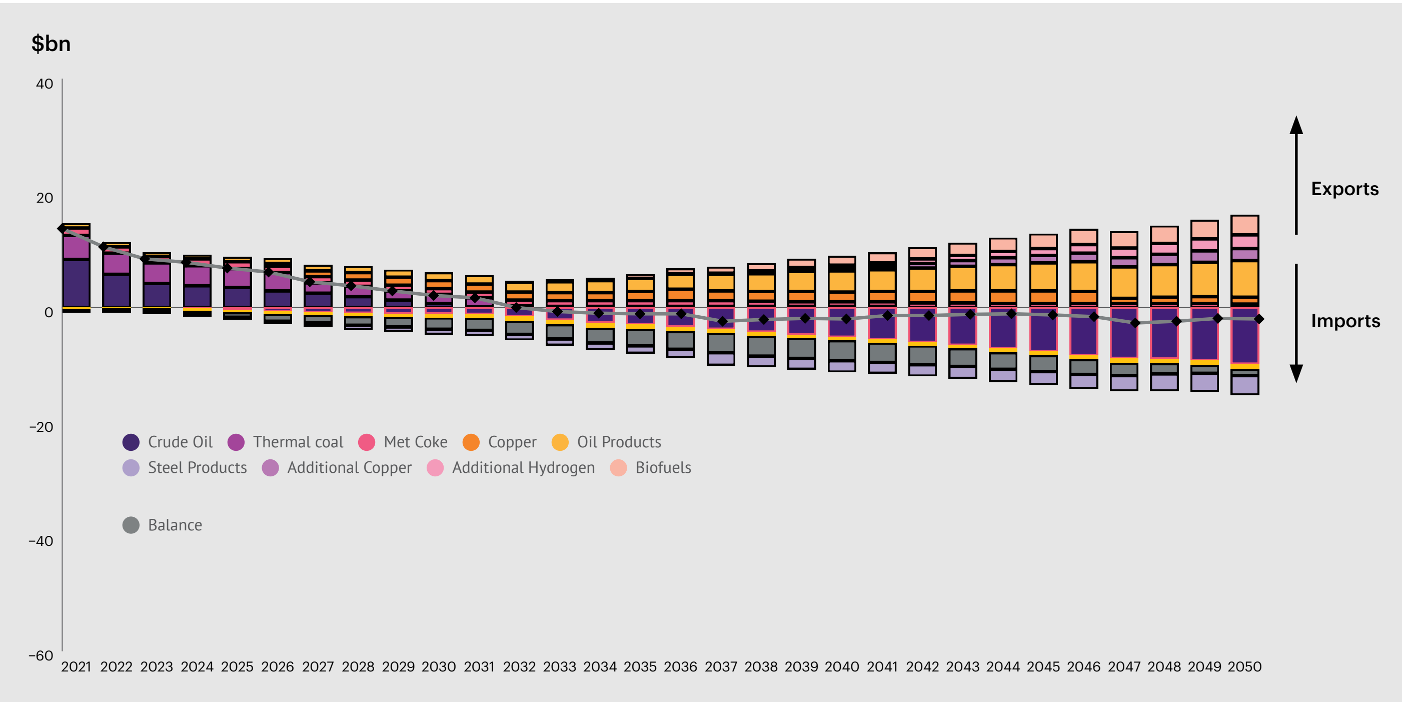


Figure 42: **Potential long-run trade balance benefits from investing in low carbon growth industries**



However, the alternative scenario presented in this paper is far from the only option. Our analysis shows that, all else being equal, the use of hydrogen fuel cells as opposed to battery electricity vehicles is likely to be an expensive option in most transport applications. However, there could be a case for incurring this incremental cost as an investment in developing hydrogen and hydrogen-related products as a potential export industry. In so doing, Colombia could use the domestic transition to incubate a new export-calibre industry.

We reviewed two potential options for the creation of new large-scale and connected export industries: hydrogen and bioenergy.

According to the hydrogen roadmap, the potential to develop Colombian demand for hydrogen is significantly higher than the level implied by bottom-up sectoral studies in transport and industry and included in our alternative transport scenario (table 63). Scaling up hydrogen to maximum capacity could displace some electricity use in transport and build a larger anchor source of demand from which to scale-up hydrogen production for transformation into export-ready products.

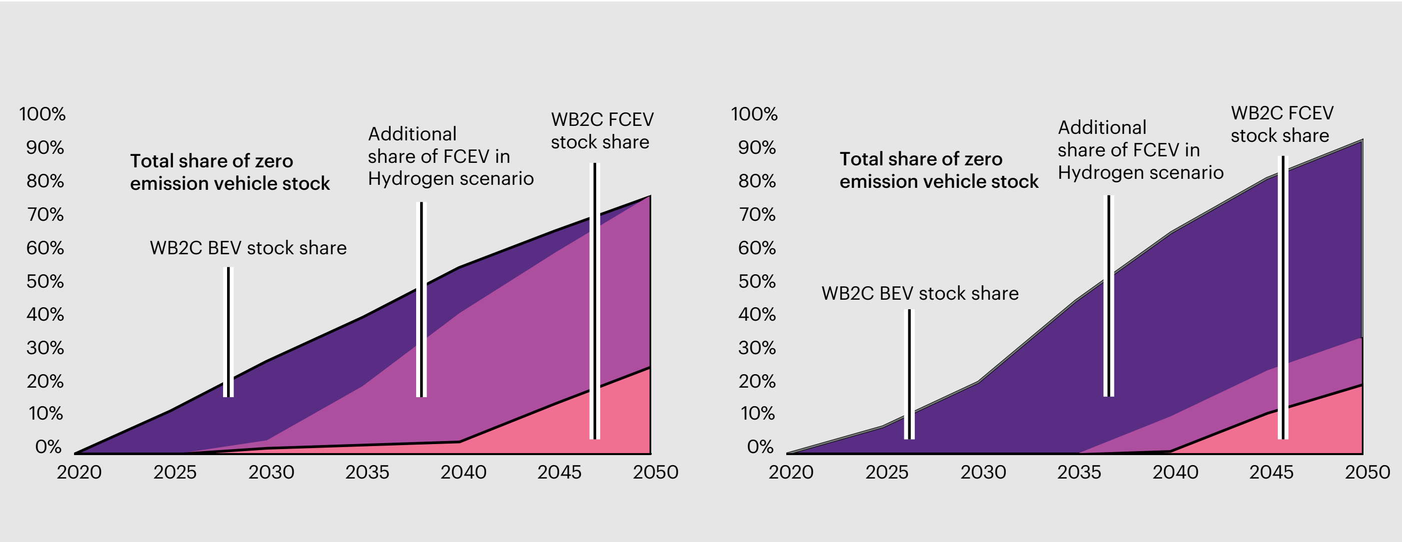
Table 63: **Domestic hydrogen demand in domestic WB2C**

		2020	2025	2030	2035	2040	2050
Industry	Kt	-	56	113	232	505	1,207
Power	Kt	-	-	-	3	32	37
Transport	Kt	-	-	7	9	23	331
Total		**0**	**56**	**120**	**244**	**560**	**1,575**

Table 64: **Domestic hydrogen demand in hydrogen sensitivity**

		2020	2025	2030	2035	2040	2050
Industry	Kt	-	56	113	232	505	1,207
Power	Kt	-	-	-	3	32	37
Transport	Kt	-	4	7	46	253	606
Total		**0**	**60**	**120**	**280**	**790**	**1,850**

Figure 43: **Options to grow the market share of hydrogen in Colombian transport. Left: Share of vehicle stock amongst road freight and buses. Right: Share of vehicle stock amongst LDVs**



A large significant hydrogen industry could help improve Colombian competitiveness on international markets by reducing Colombian production costs. According to the hydrogen roadmap, Colombia could produce green hydrogen from wind in the north of the country at a cost of $1.5/kg, a figure comparable to Chile, a country thought to be one of the likely cheapest producers of green hydrogen globally. While Chile is considering the export of hydrogen in liquid form, Colombia may have a competitive advantage through the export of hydrogen derivatives. Additional exports would provide further benefit to the trade balance (and in so doing, help to mitigate external transition risk), though it could increase the cost of the transport transition, relative to our base accelerated pathway with a higher share of battery electric vehicles and a lower share of fuel cell vehicles.

5.4.2 Accelerating the decarbonisation of the Colombian power system

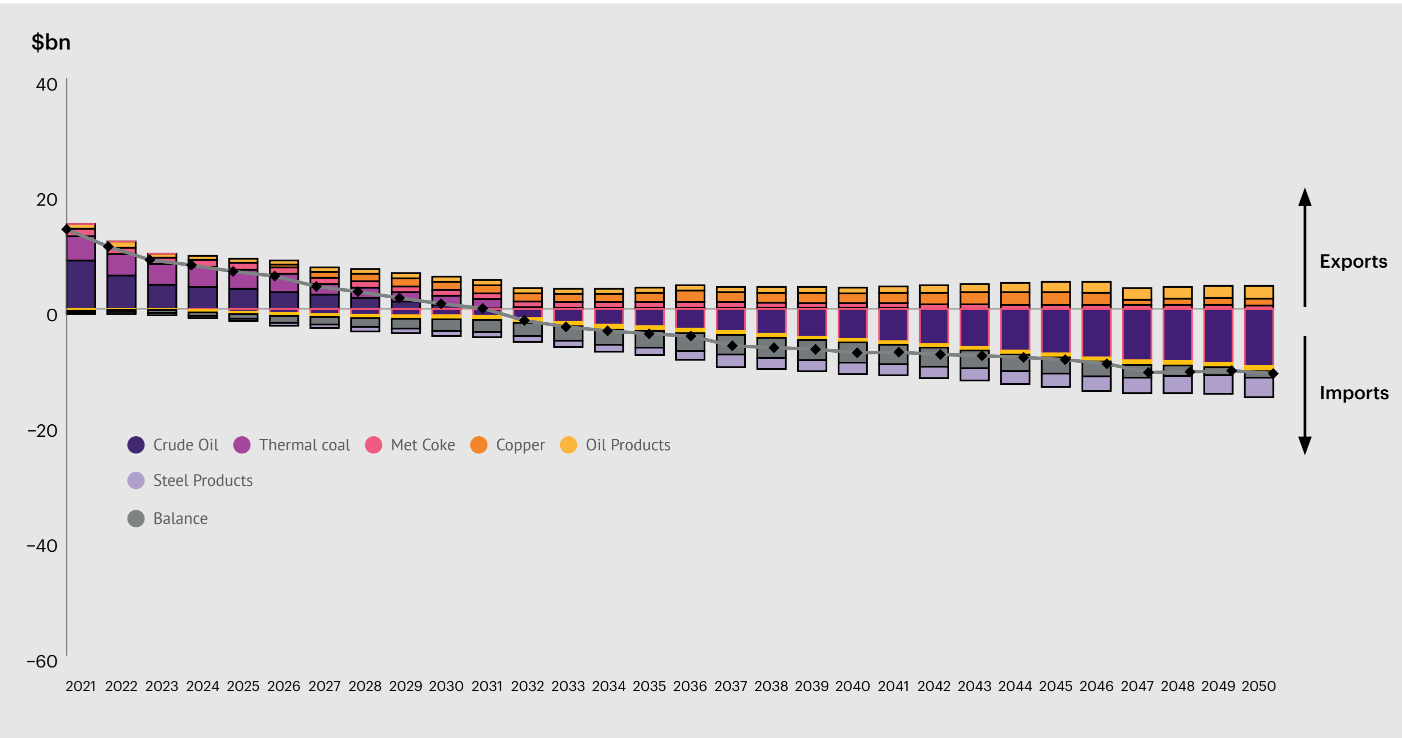
Just as faster decarbonisation of the Colombian transport sector would help to mitigate external transition risk by reducing the future import of liquid fuels, so faster decarbonisation of the power system could lead to reduced usage and import of natural gas. However, the size of this benefit would be much smaller than the benefit of the accelerated transport transition as the value of future natural gas imports to Colombia would be significantly lower than the value of future liquid fuel imports, as shown in figure 46 below (natural gas in pink, oil and oil-based products in purple).

Reducing the use of gas in the power system could have a much more powerful indirect benefit. As explored in chapters 3 and 4, unless new offshore gas finds are larger than expected and come online faster than expected, Colombian gas costs are likely to become much more closely linked to international gas prices, which we expect to rise and become more volatile in a global transition.

A long-term role for fossil fuels in the electricity system is currently assumed by UPME's PEN, though not by the E2050 vision document. According to the PEN, in 2050, Colombia would still have 4.1 GW of natural gas and coal-fired generation capacity, only 1.3GW less than in 2019, albeit running less often. If wholesale electricity market pricing remains based on marginal cost principles, maintaining gas in the system could mean importing increased gas price volatility into the electricity system, thereby potentially increasing the cost of the domestic transition and impacting the competitiveness of potential new Colombian exporters of manufactured goods. As explored in section 5.4, faster decarbonisation of the power system would be an important spur to decarbonisation of transport and industry.

Provided that removing most gas from the power system is technically possible, accelerated power system decarbonisation could have multiple benefits in reducing transition risks and costs. There remains significant debate about the ability to do this, given the need for firm back-up for a hydro-based system in El Nino years. However, developments in power systems engineering, including the incorporation of demand response; of flexible, "clean" firm generation options powered by geothermal energy, biomass; short- and long-duration energy storage are all likely to reduce reliance on fossil fuels in reliable low carbon electricity systems.

Figure 44: **Global WB2C scenario with domestic baseline**



5.4.3 Summary

Colombia has options to use its domestic transition to mitigate part of the potentially destabilising external transition risk identified in chapter 4. It can do this by prioritising the development of new export industries that would be resilient to or would benefit from that global transition (such as copper mining). Alternatively, it has options to use a particular domestic transition pathway to incubate and reduce the cost of new export-calibre industries (such as synthetic air fuels and low carbon shipping fuels) where Colombia may have a competitive advantage. Finally, accelerating the reduction in the usage fossil fuels that are currently or would, in future, be mostly imported, would also have a positive impact in mitigating the external imbalances would be a major challenge from the global transition.

However, as illustrated in figure 45 below, whilst the strategies suggested above could help mitigate long-run external transition risk, they are not likely to be available at scale until the 2030s at the earliest and are also subject to practical uncertainty about the scale-up of electricity generation and hydrogen production required to make them viable.

Ultimately, this means that Colombia – even after maximising the potential to offset or diversify – will still likely face material residual external transition that could crystallise in the 2020s, that it should take steps to mitigate.

5.5 Proactively mitigating concentrated downside risk

As explored in sections 5.3 and 5.4, no single strategy will be sufficient to offset all of Colombia's external transition risks. In addition, actions to implement Colombia's domestic transition (including those identified in 5.4 which can help to mitigate external risks) will likely create further losers as well as winners. Concentrated downside risks can have broader implications for the economy and the financial system if they sit with parties with limited risk bearing capacity, as the risks can lead to financial distress, bankruptcy and ultimately, credit losses. At the level of the macroeconomy too, the decline of a sector (crude oil extraction) characterised by very high and difficult to replace economic rents suggests that a deeply decarbonised Colombia may require a different economic model.

This section summarises the results of our work to understand the distribution of external transition risks after implementation of the strategies set out in 5.3 and 5.4 as well as the additional transition risks that would arise from the alternative domestic transition strategies proposed in this paper. These include companies and workers in sectors facing downside risk, local governments and, the national government. We also highlight several potential risk mitigation and funding options that the government can bring to bear in mitigating those risks, including the gains from lower fuel prices, public and private sources of international climate finance and financial innovation.

Figure 45: **Potential scenario with domestic WB2C scenario and alternative export revenues (illustrative)**

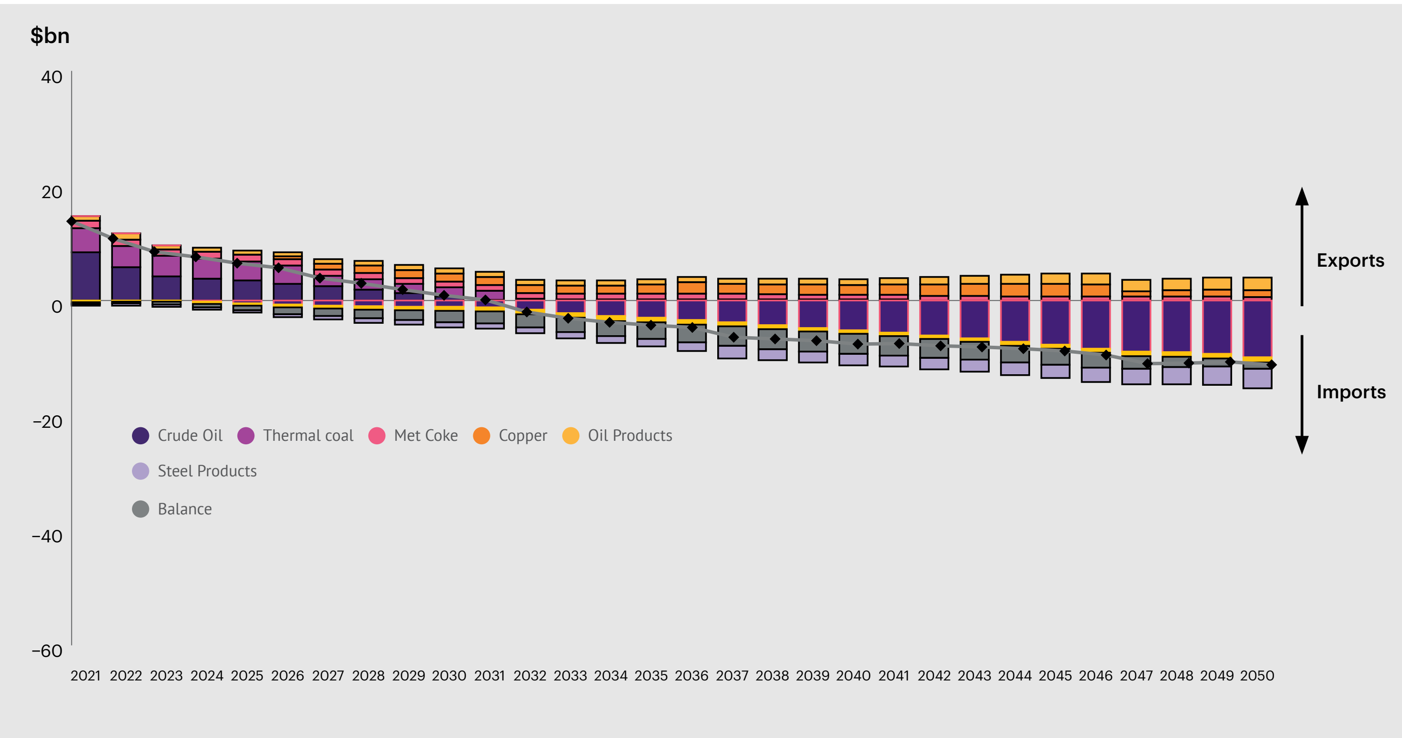


Table 65: **Summary of recommendations for proactively targeting concentrated downside risk**

Proactively target groups and regions with concentrated downside risk with funding and support	
Identifying climate transition risk concentrations	
37. Develop clear and transparent criteria about who will be eligible for state support in relation to climate transition risk, focussing on parties with limited financial flexibility and options to mitigate	**MHCP**
38. Be selective and transparent about which firms are considered for extraordinary ("bailout") support and the conditions under which that support is offered	**MHCP**
39. Incorporate an understanding of external climate transition risk exposure and risk-bearing capacity for firms and sectors when considering the potential costs and benefits of different domestic transition mechanisms (such as carbon pricing)	**MHCP, DNP**
Options for mitigating climate transition downside	
40. Develop roadmap for designing transition funding and support packages for workers, and communities at risk, drawing on learnings from international and Colombian precedent	**DNP, MHCP**
41. Develop roadmap for short-term support and long-term changes to local government funding mechanisms to adapt to a structural decline in fossil fuel rents	**DNP, MHCP**
42. Set up regional transition commissions co-chaired by national and local governments and including the explicit involvement of civil society organisations	**DNP, MinAmbiente**
43. Use fiscal and subsidy mechanisms to capture a share of gains accruing to firms and consumers from lower electricity and transport system costs in a lower carbon Colombia	**MHCP**
44. Design and implement a new fiscal mechanism to capture "excess" profits from coal and oil industries - to be used to finance transition initiatives across the economy. Consider a mechanism with longevity beyond the war in Ukraine to capture a share of future commodity price spikes as part of a global transition	**MHCP, DNP**
45. Access internationally available sources of Just Energy Transition Partnership (JETP) funding, to help fund structural change and the potentially severe socio-economic impacts of the decline of key export industries	**MHCP, DNP**
46. Access internationally available sources of philanthropic funding, to be used to invest in and lower the cost of capital for new technologies, deal with concentrated areas of transition risk to prevent systemic issues and help fund training costs to build the technical acumen of public servants	**MHCP, DNP**

5.5.1 Identifying concentrated downside risk from global and domestic transitions

In Chapter 4, we identified concentrated risks that – unless urgent action is taken to diversify and reduce risk – could prove to be beyond the risk-bearing capacity of those that are exposed to the risk. In particular, we highlighted coal mining companies, independent oil and gas producers, thermal coal mining workers, and local governments (particularly La Guajira, Córdoba, Meta and Cesar at the department level) as facing particular challenges.

For those small firms, workers and local governments, the strategies set out in sections 5.3 and 5.4 may have limited impact, if alternative industries are not concentrated in similar regions and do not provide jobs requiring similar skills. Workers and local governments may have particularly limited financial flexibility while some firms may have options to diversify their businesses to new sectors that are more resilient to the transition. Larger firms with lower leverage, such as Ecopetrol, will have more flexibility to do this than smaller, more leveraged firms (such as Frontera Energy) although all face uncertainty about the speed of the transition[394] and could face challenges from declining access to capital and insurance depending on the evolution of the ESG trend in the financial industry.

394. Firms in sectors where there is relative consensus that they face relatively clear long-run decline in a WB2C scenario (such as coal and oil) face particular uncertainty about the speed of the transition – whether it makes sense to shift business model today and potentially forego revenues in the short run or to wait to earn short term revenues (which might be used to finance a transition), but then running the risk of having to make a sharper transition later. A former client of one of the authors previously described this dilemma as trying to understand "how long is my runway?"

Some of the same firms that face material exposure to external transition risk could also have significant exposure to domestic transition risk, including Ecopetrol, whose oil refining and marketing operations would be negatively by an accelerated decline in demand for those fuels. Others, including firms in power generation and industry, while largely protected from the external transition, could face downside risk from the domestic transition, depending on the policies used to implement it.

5.5.1.1. Domestic transition risk in power generation

Assets and firms in Colombia's power generation sector face domestic transition risk both from the expected changes in Colombia's generation stack and from potential reforms to the design of the electricity market. The latter are being widely pursued internationally to align risk and incentives with the changing physical nature of electricity generation resources[395]. For Colombian power generation firms, this could mean that the domestic transition impacts both revenues (via changes to running hours, wholesale electricity market prices and capacity market design) and costs. Furthermore, the carbon tax will likely add risk for coal and more inefficient gas plants, though the extent to which those plants are able to mitigate those risks via the purchase of carbon credits remains unclear.

What is clearer is the government's high-level plan for growing the share of non-hydro renewables and the growing electrification of transport and industry. However, the implied emissions trajectory for the sector as a whole (from the E2050) suggests that faster declines in the use of coal and natural gas will be required, compared with the PEN.

Extrapolating from the E2050 trajectory (which was not derived from an electricity systems model) to a scenario from which to run climate transition risk analysis, was not easy. Implied electricity demand must grow faster in the E2050 than in the PEN due particularly to deeper decarbonisation in industry. On the supply side, we needed to understand the asset-level and system constraints with integrating large amounts of variable renewable energy plants, the options for resolving those constraints and the potential costs. Table 67 sets out our understanding of the key potential issues to be resolved. To understand the potential solutions, we also drew on experience of the authors in working with deeply decarbonising power systems and the growing international range of electricity system modelling studies, including in hydro-rich systems[396].

Table 66: **Electricity generation – share in % from coal and natural gas**

	2020	2030	2040	2050
PEN – coal	11	5	4	4
PEN – gas	24	9	6	12
PEN – total fossil	**35**	**14**	**10**	**16**
E2050 – coal	11	9	-	-
E2050 – gas	24	9	5	-
E2050 – total fossil	**35**	**18**	**5**	**0**

395. The UK's ongoing Review of Electricity Market Arrangements (REMA), launched in August 2022, is one of the more comprehensive attempts to understand the potentially benefits of different competing future electricity market designs better suited to a lower carbon world dominated by high fixed cost/low variable cost generation. Source: https://www.gov.uk/government/news/uk-launches-biggest-electricity-market-reform-in-a-generation (Accessed 26 August 2022)
396. National Grid's Future Energy Scenarios (https://www.nationalgrideso.com/future-energy/future-energy-scenarios) is a good example in the UK context. In Colombia, the academic sector is making an important contribution towards mapping the potential of zero carbon electricity systems, particularly: https://www.sciencedirect.com/science/article/abs/pii/S0360544221024051

Table 67: **Key practical issues to be addressed to enable faster scale-up of low carbon power in Colombia**

Key issues / uncertainties	Potential solutions
Uncertainty about timing and final capacity of Hidroituango	Accelerated wind and solar investment
Transmission constraint between Caribbean and interior zones	Enhanced transmission investment in the medium term. In the short-term, clustering within the north of the country of renewable energy generation, green hydrogen production and hydrogen consumption.
Flexibility and ramping costs of reservoir hydro	Run shadow auctions alongside next reliability option auctions for new flexibility (as opposed to capacity / reliability) services to understand the technical constraints and relative costs of non-hydro flexibility options
Minimum generation levels and ramping costs of coal and natural gas plants	As above
Need for "clean" backup capacity to cover for hydro shortages in El Niño years	Accelerate pilots for "clean firm" dispatchable generation, including geothermal, biomass/biofuels and green hydrogen/ammonia. With hydrogen/ammonia, this could include blending in natural gas turbines and/or co-firing with coal[397] .
Major investment required to expand generation capacity	Introduce policies to reduce the cost of capital for renewables investments, including the introduction of long-term PPAs with firm prices and clarifying the rules about competition for curtailment. Retail electricity price reform could also be key (as in next section).
Major investment required to expand electricity transmission and distribution networks	Where investment capacity is constrained, consider adjusting regulatory frameworks to provide accelerated investment recover. Retail electricity price reform could also be key (as in next section).
Opportunities to reduce system costs at transmission and distribution network level, including energy efficiency, flexible demand, short-term and longer-term storage	Develop a transparent, open-source electricity systems model demonstrating cost assumptions and potential trade-offs with local flexibility options which may reduce the need for expensive transmission and distribution network investment.

Lower long-run generation from coal and natural gas plants in a faster decarbonisation scenario (in line with the E2050 vision) would result in substantially lower demand for those fuels (and hence lower revenues for their producers). However, the extent to which faster decarbonisation would result in lower profits for fossil fuel power generators will depend to a large extent on the evolution of Colombia's power market design.

To understand the implications of a faster transition in line with the E2050 vision, we built a simple Excel-based dispatch model to understand the impact wholesale and contract market pricing, as well as on the running hours of fossil coal- and gas-fired plants. To build this model, we gathered information about coal and gas-plant efficiency, fuel costs, wind, and solar resource profiles, seasonal and intra-year hydro availability as well as contracted and expected additional revenues relating to reliability and transmission constraints. We consulted with market experts and research to develop a proxy for wholesale electricity market pricing and economic dispatch, based on short-run marginal cost[398] and incorporating different scenarios for electricity demand and carbon pricing.

Simply put, the profits of any given power plant will be a function of a) the amount that it generates, b) the level of contracted or wholesale market prices that it captures when generating and c) the amount of additional revenues it earns for providing additional system services, including stand-by capacity or reliability.

397. There is increasing confidence that hydrogen might be able to play an important role in the power system, both as a means of storing excess wind or solar energy and for occasional use as a generation fuel. See: https://www.rechargenews.com/energy-transition/why-hydrogen-fired-power-plants-will-play-a-major-role-in-the-energy-transition/2-1-1045768
398. This model contained a number of important simplifications. We did not have access to information about the risks imposed on generators arising from their participation in markets, the obligations placed on plants to provide services to stabilise the system and the remuneration paid for those services. The most important uncertainty relates to the policies used to stimulate additional generation over the long-term (including carbon pricing)

In a market with limited physical constraints, the amount that any available coal or gas-fired power plant would generate in any one period generate in any one period will depend on a) total system demand, b) the amount of cheaper hydro and non-hydro renewables available in that period and c) the relative competitiveness between fossil power plants on the basis of short run marginal cost. In practice, the actual dispatch of Colombia's fossil fuel power plants does not always follow this principle, as transmission constraints between the north and centre of the country mean that fossil fuelled power stations in the north often need to run more often than would otherwise be cost effective[399] (this is called "out of merit generation"). Certain power plants in the north of the country could therefore face downside risk as transmission capacity is increased.

Fuel costs[400] are currently the major drivers of competitiveness between coal and gas-fired power stations. However, with the implementation of the 2022 tax reform, a growing carbon cost could flip the relative competitiveness of those two fuels. As shown in table 68, our analysis suggests that a higher carbon price of only around $10/t would be required to cause coal to gas switching in power generation.

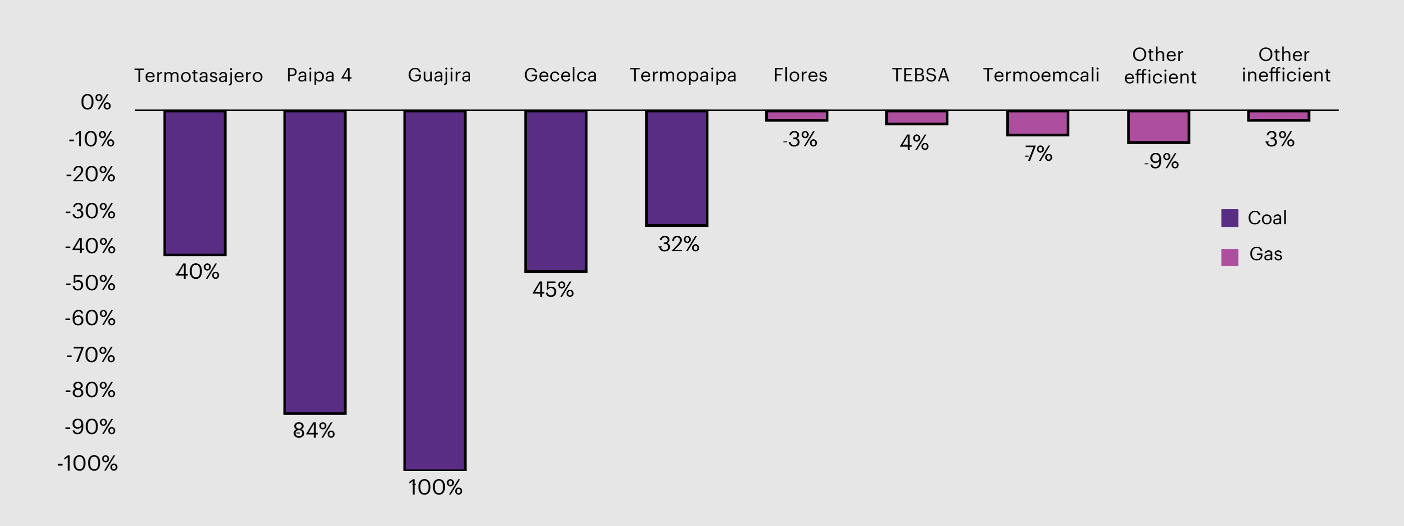
The short-term impact of the tax reform[401] is likely to have limited influence on the number of hours that thermal plants (in total) run[403] , but it would impair the competitiveness of coal-fired power plants compared with efficient gas-fired ones (particularly more flexible combined cycle gas fired turbines or CCGTs). In a scenario with a $15 per tonne carbon price and faster electrification of transport and industry, coal-fired power stations would lose substantially all their value while natural gas plants remain relatively resilient. However, if deployment of new renewable energy generation capacity were to be delayed[404] and did not keep up with a rise in demand, there could be a short-term boost to operating hours and thermal plant profitability.

Table 68: **Estimated costs of Colombian thermal generation based on 2021 prices (with and without carbon taxes at various levels)**

Costs	Coal	Higher efficiency gas	Lower efficiency gas
Plant efficiency	37%	46%	41%
Base fuel cost / MWh	20	34	38
Variable O&M	10	3	3
Short-run marginal cost (SRMC) without carbon tax	**30**	**37**	**41**
Carbon tax @ $5/t	5	1	1
Carbon tax @ $10/t	9	2	3
Carbon tax @ $15/t	14	4	4
SRMC with $5/t tax	**35**	**38**	**42**
SRMC with $10/t tax	**39**	**39**	**44**
SRMC with $15/t tax	**44**	**41**	**45**

399. Termocandelaria is a particular beneficiary of those transmission constraints and is cited by rating agencies as an important credit positive. See: https://www.fitchratings.com/research/corporate-finance/fitch-affirms-termocandelaria-power-sa-at-bb-outlook-stable-28-04-2022
400. Because Colombian coal and natural gas supply has historically been governed by bilateral contracts, rather than wholesale markets, different plants have different fuel contracts with potentially very different fuel costs, depending on distance from the relevant mines and wells
401. In practice, there has been criticism of the existing scheme because of the ability to use offsets (including renewable energy investments) to offset tax liabilities and the limited measurement, reporting and verification (MRV) obligations around those offsets. Nonetheless, both the Duque and Petro administrations appear to support economy-wide carbon pricing measures, for example, via an emissions-trading scheme and by the integration of some Colombian assets into international carbon markets.
402. Because thermal plants already have higher SRMC than hydro or non-hydro renewables
403. For a summary of potential delays, see: https://theglobalamericans.org/2021/11/colombia-a-renewable-energy-powerhouse/
404. By contrast, more flexible power plants, such as reservoir hydro, could benefit from such a change

Figure 46: **Domestic transition risk across major thermal power generators**



Declining running hours would make coal fired power plants more reliant on capacity payments under the Cargo de confiabilidad (the "reliability charge"), in the same way that the least efficient gas-fired power stations currently are. Less flexible plants would be exposed to downside risk in the event of a change in market design that values flexibility, rather than capacity[405]. It is not possible to quantify this risk precisely, but different plants would be exposed to a change at different times, depending on the tenor of their existing reliability option contracts.

In the long run, the feasibility of thermal power plants continuing to operate into the 2030s and 2040s will depend on the availability of CCUS technology at reasonable cost. Set against CCUS, whose costs are very site specific are fast developing new technologies in electricity storage, demand response, and "clean firm" power capacity (for example, hydrogen or geothermal)

Table 69: **Reliability option tenors (GW)**

Expiry date	Coal	Gas	Hydro	Wind and solar
2023	1.1	1.2	10.6	0.1
2025	-	2.1	-	-
2028	-	0.4	-	-
2032	0.2	0.3	0.4	-
2034	-	-	0.6	-
2035	0.4	-	-	-
2037	-	-	-	-
2038	-	0.1	2.2	-
2042	-	0.8	0.1	1.3

which may eventually provide a cheaper and more reliable means of providing to the Colombian power system everything from day-night flexibility to baseload backup in dry El Niño years.

Wind and solar are likely to be insulated from climate transition risk in the wholesale market as their revenues are secured by long-term PPAs allocated through auction[406]. However, the speed of their deployment will be material for the question of the level of risk faced by thermal and hydro plants[407], The extent to which a growth in wind and solar (or other low marginal cost zero carbon technology) generation capacity reduces the running hours of fossil capacity depends on the amount and pace of new generation additions, compared with the rate of demand growth. If new generation is added but does not keep pace with demand growth, the running hours of thermal generation will rise, creating short term upside. If new generation is added faster than demand growth, new zero marginal cost generation will erode the market share of coal, gas, and some hydro plants and result in lower average wholesale prices, creating downside climate transition risk.

Within the power generation system, the companies most likely to face downside climate transition risk (triggered by the carbon tax) in the short run are owners of coal-fired power stations (Gecelca, Guajira, and Paipa plants are state-owned, while Termozipa and Termotasajero are privately held). Owners of gas plants reliant on transmission constraints (Termocandelaria) and with relatively inflexible technical characteristics are likely to face longer term risks relating to the paradigm shifts in the Colombian system (transmission expansion, reform of market design) that may be required to enable the country to add enough renewable energy capacity to meet growing demand from transport and industry.

405. For a summary of the conditions in Colombia's renewable energy auctions, see: https://irena.org/publications/2021/March/Renewable-energy-auctions-in-Colombia
406. Hydro plants (particularly inflexible run-of-river plants which represent a small part of Colombia's generation stack) can be "price-takers" given their low marginal cost and so their profitability will be directly affected by the level of the wholesale price (subject to hedging). Reservoir hydro (which makes up the majority of Colombia's generation stack) is more flexible (although we were not able to ascertain the technical limits of this flexibility) and is more likely to operate in a balancing capacity.
407. Source: http://www.ideam.gov.co/documents/24277/77448440/PNUD-IDEAM_2RBA.pdf

5.5.1.2. Domestic transition risk in industrial sectors

Assets and firms in Colombia's industrial sectors face domestic transition risk because uncertainty about the speed and shape of Colombia's long-term policy ambitions for those sectors means that deep decarbonisation is not yet factored into planning. What we can be relatively confident about is that however Colombia decides to incentivise decarbonisation, it will need different approaches (and technologies) for different types of industrial processes.

Historically, between 30-40% of emissions from Colombian industrial sectors have been in fuel manufacturing businesses (liquid fuels and coke), with the rest principally deriving from the generation of heat (both direct and indirect) and for use in chemical reactions. The 2014 total of 34.4 million tonnes of CO2 equivalent was more than twice the amount of emissions than from power generation[408].

According to the Plan Energético Nacional's most ambitious Disrupción scenario, the largest contributors to final energy demand for Colombian industry in 2050 are natural gas (29%), biomass and waste (23%) and electricity (21%), with the rest being made of hydrogen (15%), coal (11%) and oil (1%). In that scenario, CO2 emissions in 2050 total 12.4 million tonnes, a significant reduction on the total for 2014, and a much higher reduction in CO2 intensity. However, the scenario would fall short of the E2050 vision unless the country is very successful than it expects in deploying CCUS.

Table 70: **Industrial emissions in Colombia (2014, mt CO2 equivalent)**

Sector	2014 energy emissions	2014 process emissions
Liquid fuels	2.6	-
Coke and other solid fuels	8.8	-
Total energy industries	**11.4**	-
Iron, steel, and ferroalloys	-	1.6
Total reducing agents	-	**1.6**
Iron, steel, and ferroalloys	0.9	-
Non-metallic minerals (cement, bricks, glass, lime)	6.1	5.3
Total direct heat	**7.0**	**5.3**
Pulp, paper, and cardboard	1.7	-
Food, drinks, and tobacco	2.4	-
Textiles	1.1	-
Total indirect heat	**5.2**	-
Chemicals	1.2	0.6
Other	2.1	-
Total direct and indirect heat	**3.3**	**0.6**
Total	**26.9**	**7.5**

408. Though the 2022 tax reform retains an exemption for coking coal

Table 71: **Alternative WB2C scenario for Colombian industry**

	2014	2020	2030	2040	2050
Oil refining	3	3	2	3	-
Coke production	9	10	10	5	-
Other industry (energy)	14	14	10	6	2
Other industry (process)	8	8	7	6	1
Total	**34**	**35**	**29**	**20**	**3**

Unlike in power generation, transport or land use sectors, the industrial sector is one where the low carbon technologies capable of substituting fossil fuels are not uniformly available, particularly at commercial scale. In reality, industrial processes are heterogeneous and complex and while low carbon technology options may be proved and straightforward in some circumstances (for example, in the use of industrial heat pumps for low temperature heat), in others, such as the use of hydrogen in direct reduction of iron or the use of calcined clays in concrete production, are still at the pilot stage. However, the primary products of industrial activity, such as steel, concrete, chemicals and glass, are the core building blocks of industrial development and demand for them, in the absence of alternative materials, is only likely to rise over time as economies grow.

Despite their "hard-to-abate" nature, in some senses, it is more critical for governments to think early about the paths for decarbonising industry than transport, given the much longer asset lives in many industries. Unlike cars, which may not be used for many more than ten years, industrial assets like brick kilns and sugar refineries may last a lot longer. If Colombian industry locks in unabated use of coal and natural gas via its next cycle of investment decisions, it could suffer material downside climate transition risk in a WB2C scenario. Locking in long term use of coal and natural gas in industry would also make Colombia more dependent than it needs to be on CCUS to meet its national goals.

To consider the domestic transition downside in industry, we constructed an alternative industrial decarbonisation scenario designed to be consistent with our power and transport scenarios in reducing total Colombian non-AFOLU emissions to a figure in line with the E2050 vision. In this scenario, net industrial emissions falling to only 3 tonnes in 2050 net of captured and stored CO2.

The future emissions trend for both oil refining and coke production will be impacted by both global and domestic transitions. For coke, with domestic consumption (at the Paz del Rio steel plant) using up only 20% of domestic production, with the rest exported and subject to external transition risk, as described in section 4. For oil refining, while the volume of Colombian production is affected by competition from imports, the speed of the domestic transition in transport, as the primary driver of declining demand for oil-based fuels, is likely to be the major driver of transition. For companies in these industries, the impact of transition risk will largely be through a reduction in revenue, reducing from lower demand driving lower sales volume and, in some cases, lower prices.

For other industrial sectors, where we expect that demand might remain resilient in a low carbon scenario, transition risk is more likely to materialise through an increase in costs. In the first instance, this could be through an increase in operating costs (via a carbon price designed to incentivise switching to low carbon processes[409]) and ultimately through an increase in capital costs (to retrofit existing production facilities with carbon capture or renewable electricity sources). These dynamics may prompt certain firms to close assets with existing processes and to build new ones if that proves cheaper than the cost of mitigating emissions at existing assets.

Increasing costs could expose Colombian industry to the risk of import substitution, although Colombia's current inland infrastructure challenges will likely be a barrier to that. Increased costs also open the potential for material substitution[410] and should provide a greater incentive for greater material efficiency, including greater circular economy strategies. These technology- and market-specific challenges - and the policies devised to incentivise industrial decarbonisation - will be the principal determinants as to which assets, firms and economic groups (for example, consumers), ultimately end up being the bearer of this transition risk.

409. For example, the use of cross-laminated timber as a substitute for concrete in building (https://www.energy-transitions.org/wp-content/uploads/2020/08/ETC-sectoral-focus-Cement_final.pdf)

5.5.1.2.1. Fuel production

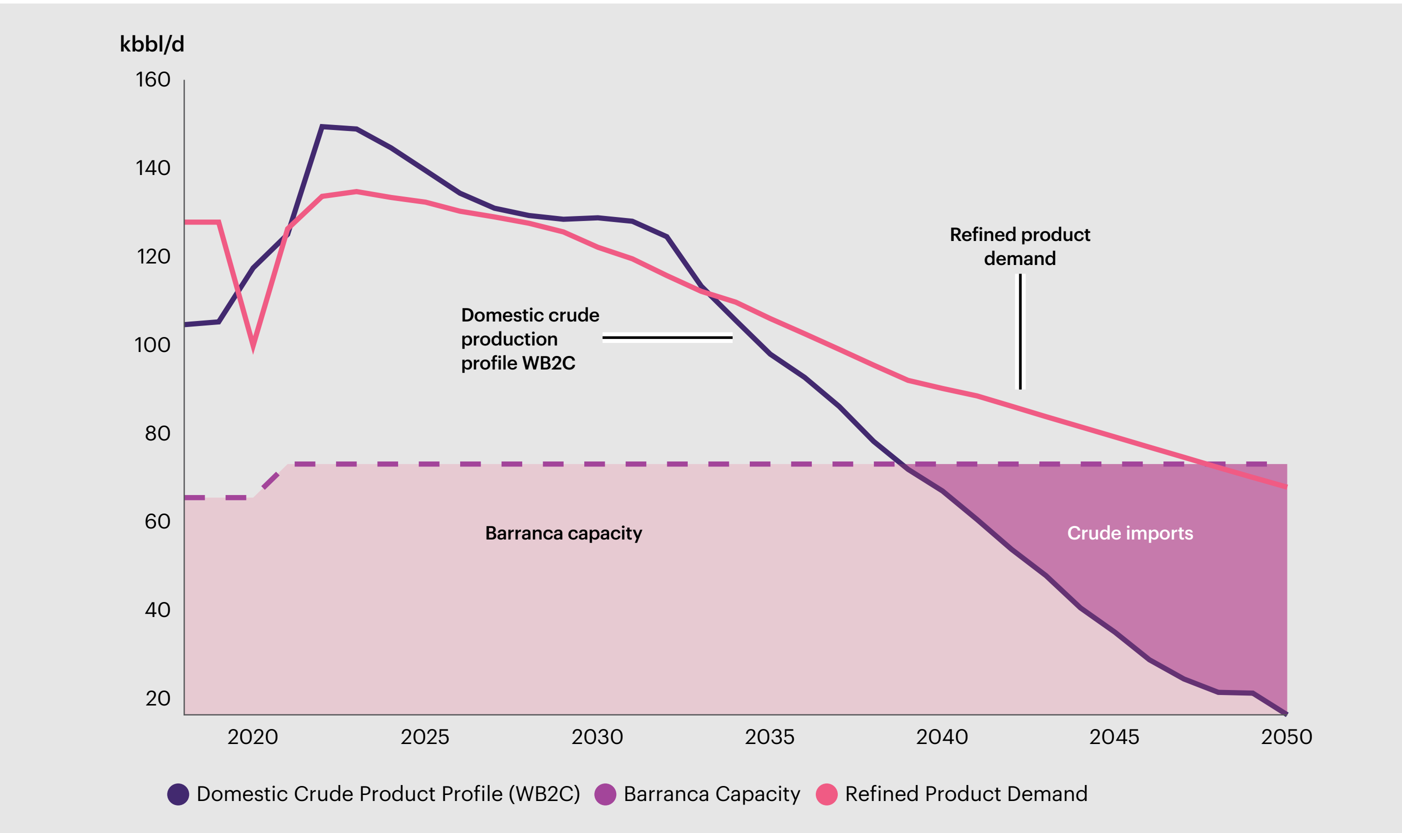
The oil and gas value chain is one of the areas certain to be affected by both external and domestic transition risk. As explored in chapter 4, Colombia's oil refineries would face downside transition risk from a global transition, via lower margins, even though demand for liquid fuels might continue to rise in Colombia. Rising demand would lead to an increase in Colombian fuel imports as demand outstripped the production capacity of Colombian refineries but the decline in the availability of Colombian crude (in both BAU and WB2C scenarios, resulting in an increase in crude imports), combined with lower product margins would reduce earnings for Colombian refineries starting in the 2030s and make Barrancabermeja vulnerable to early closure by the late 2030s.

An accelerated Colombian transport decarbonisation of the sort discussed in section 5.3 would reduce demand for liquid fuels in Colombia on top of the above dynamics. However, our analysis shows that the domestic transition would not add transition risk for Colombian refineries over and above that arising from the global transition. As illustrated in figure 47, lower Colombian demand (or demand growth in the early years) would mean lower imports in the 2020s but not affect Colombian production. As Colombian demand starts to fall below the combined production capacity of the country, the country's refineries could face transition risk, although our analysis suggests that Cartagena would be well placed to export any product that it cannot sell in the country. Barrancabermeja remains most vulnerable, but our analysis shows that the domestic transition would not have an incremental impact on its economic viability as the asset would already be persistently loss-making because of external transition risk (see section 3.2.2).

With coke, similarly, our analysis suggested that while Colombia may be able to expand its sales to non-steel industries[411], the impact of the global transition in the steel industry on Colombia's coke producers would be very negative over the long term. In addition, a domestic transition in Colombia that reduced emissions in steel production would mean a further reduction in coke use, unless CCUS could be retrofitted to Paz del Rio's steelworks and to some of the coke production facilities. This could be very costly given the age and complexity of Paz del Rio's operations.

The practical challenges of retrofitting CCUS to BOF-BF steelworks like Paz del Rio means that, with some exceptions in China, steel analysts are increasingly reconciled to the fact that the continued operation of BF-BOF steelworks much beyond 2040 will not be compatible with a deeply decarbonised primary steel industry. Instead, HISarna or hydrogen DRI processes are being explored. HISarna is seen as a promising candidate because it enables the use of lower quality iron ore fines and hence avoids the energy intensive

Figure 47: **Demand of refined products in a domestic WB2C, compared against Barrancabermeja capacity**



410. See section 4.3.3

"sintering" (or agglomeration) process, but it does use powdered coal and oxygen in a "smelt reduction vessel" to produce the required hot metal. HISarna therefore needs to be equipped with CCUS to be viable in a deeply decarbonised world. By contrast, while direct reduction of iron, using green (or blue) hydrogen, avoids the use of coal entirely, the process works only with iron ore pellets[412].

What this means is that Paz del Rio's steelworks would be likely to close in a deeply decarbonised Colombia. Whether Colombia is able to continue producing primary steel after this point will depend on the cost of a future Colombian HlSarna with CCUS or hydrogen DRI plant.

In conclusion, our analysis suggests that the domestic transition could have relatively little incremental impact on energy production industries in Colombia, though coke and primary steel production could be affected to a greater degree than liquid fuel production by these dynamics.

5.5.1.2.2. Other industries

The exposure to other Colombian industries of a domestic transition that results in increased costs will, like steel, be affected principally by the technical ability to replace coal, coke, oil and gas with other products, the ability to pass those costs through to consumers and the extent of import substitution risk. The greater technological challenges with decarbonising "direct heat" processes may mean that these are decarbonised later than those with "indirect heat" processes.

In the production of direct heat (i.e., where fuels and raw materials are heated together in the same vessel, such as a kiln), there may be more restrictions initially on using alternative materials to coal and natural gas, due to concerns about the potential impact of using alternative materials (such as waste) on the quality of the final product.

Electric heating sources are typically more energy efficient on a whole system basis than hydrogen heating, as they avoid the extra energy required to produce hydrogen via electrolysis. However, for high temperature heat (>250C), electric process heat is not yet a proven technology option[413]. Here clean hydrogen may generally be a technologically effective substitute for coal and natural gas, especially given the former's relatively high energy density[414]. The eventual decarbonisation pathways for Colombian cement/concrete, brick, glass, and lime industries will, despite their common current reliance on coal and natural gas to provide high temperature heat, likely be varied, due to a range of practical considerations.

For example, decarbonisation of cement production is one of the few industrial processes, where abatement with CCUS seems almost inevitable, given that process emissions (from the heating of limestone as raw material) represent around half of the total emissions in the cement/concrete making progress. The global industry, spearheaded by LafargeHolcim, the company with the third largest share in Colombia, has advanced several CCUS pilots around Europe, meaning that Colombia will likely be able to draw on significant international expertise as to the most appropriate capture technology / configuration to use in Colombia.

Table 72: **Industrial consumption of coal in Colombia (kt)**[415]

	2018	2019	2020
Food (sugar refining)	594	935	514
Textiles	459	138	95
Pulp and paper	434	435	415
Chemicals	118	124	104
Non-metallic minerals (cement, brick, glass)	1,247	1,399	1,238
Other industry	114	114	182
Total	**2,966**	**3,145**	**2,548**

411. The yet more nascent electrochemical reduction process may yet solve some of the technological challenges with both HISarna and H2-DRI processes.
412. For a summary of potential industrial decarbonisation option, see : https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/824592/industrial-fuel-switching.pdf
413. Hydrogen has an energy density of 150Mj/kg, which is three times more than either diesel or gasoline. Source: https://rmi.org/run-on-less-with-hydrogen-fuel-cells/#:~:text=By%20contrast%2C%20hydrogen%20has%20an,12%E2%80%9314%20kWh%20per%20kg.
414. Information taken from: BECO https://www1.upme.gov.co/DemandayEficiencia/Paginas/BECO.aspx
415. See: https://journal.poligran.edu.co/index.php/libros/article/view/1995 for an assessment of the environmental impacts of Colombian biofuels, with a comparison of those made from sugarcane and ethanol and those made from palm oil

Compared with the cement/concrete sector that is relatively consolidated and dominated by a few large players, other Colombian industries that are dependent on high temperature heat – bricks and glass – are highly dispersed and artisanal, with over 1,300 firms active in the brick industry and over 500 firms in the glass industry. Even if an extensive CO2 transport and storage network is developed in Colombia, CCUS is unlikely to be an attractive option for these small firms, given the capital intensity of the capture equipment. Instead, partial co-firing with biomass may be an option in the short-term, with the later replacement of coal-based processes with hydrogen-based processes.

With indirect heat – where boilers are used to generate steam, which is then used in processes, such as drying – the choice of heat source is much more flexible. In this case, for firms active in industries that do not require high temperature heat – such as sugar refining, pulp and paper and textiles – replacing coal and natural gas with electrification could be relatively straightforward, if firms had access to capital and knowhow. These industries are currently some of the largest industrial consumers of coal in Colombia.

Of these sectors, textiles is the least concentrated and least integrated, with [hundreds] of firms producing mainly knitted products. Coal is used in the sector as a source of heat, primarily in the washing processes, but since these are low heat processes, the sector seems like a prime candidate for electrification.

The sugar refining and pulp and paper industries are partially integrated, as part of the bagasse residue from sugar production is used as a raw material in paper production[416]. The Colombian paper industry already faces a challenging situation, with structural changes in the demand profile for its products being driven by the digitalisation trend[417] and with a structural shortage of virgin wood raw material. The latter means that Colombian paper mills are dependent on the import of pulp and hence exposed to changing prices in international markets. Colombian paper mills typically use coal to produce electricity and steam in combined heat and power application (CHPs) to supplement the energy provided by the combustion of the "black liquor" produced as a by-product of the chemical pulping process. In a similar way, Colombian sugar refineries typically use coal in CHPs, in this case, co-firing with bagasse residue from the sugar-making process. Unlike paper mills, sugar refineries also have an important secondary role in the Colombian system as back-up providers of electricity to the grid, increasing their excess generation (and coal consumption) in El Nino years when there is limited hydro availability.

Decarbonisation pathways in industrial sectors typically rely on incremental actions, such as those relating to energy efficiency and raw material substitution (such as clinker substitution in cement production). However, in deep decarbonisation will require tailored actions to tackle practical and business model constraints, as well as challenges around access to capital and, potentially, incremental marginal cost.

Table 73: **Practical considerations with Colombian industrial decarbonisation**

	Type of process	Deep decarbonisation options	Practical challenges
Food (sugar refining)	Low temperature heat	Replacement of coal with supplementary sugarcane residues (SCR); Alternative bioenergy source	Business model reliance on electricity sales; Potential impact on product quality with other fuels
Textiles	Low temperature heat	Electrification / hydrogen	Dispersed process, split between many different locations; Competitive pressure on costs from imports
Pulp and paper	Low temperature heat	Electrification / hydrogen	No particular practical challenge
Cement / concrete	High temperature heat / process emissions	Hydrogen / CCUS	Process emissions
Primary iron / steel	Reducing agent / high temperature heat	Hydrogen / CCUS	Process emissions; Material constraints for H2-DRI

416. See: https://www.iea.org/reports/pulp-and-paper for an overview of how decarbonisation issues might impact the pulp and paper industry
417. Whether Colombia is a competitive future producer of primary steel would depend on the cost to build alternative primary steel capacity using smelt reduction with CCUS, hydrogen DRI (or some as yet uncertain technology) vs. the cost of importing primary steel from countries that have introduced those new technologies. Key uncertainties remain about the potential cost of CCS in Colombia and the quality of Colombia's iron resources (i.e. whether they are the pellet grade required for use in DRI plants.

Across most of Colombia's industrial sectors, the incremental costs required to decarbonise may mean that it does not make economic sense for firms to undertake decarbonisation investments unless otherwise incentivised to do so, potentially through a predictable rising carbon price.

Except for oil-based liquid fuels and natural gas in refining and chemicals industries, Colombia's industries have, so far, avoided exposure to carbon pricing. Carbon pricing would almost certainly be successful in raising awareness about carbon intensity and incentivising investments in R&D and material and business model innovation. It could help to reduce the relative operating cost differential with low carbon alternatives, but only if firms are mostly able to pass through the increased cost to consumers. If they are not able to do this, the additional cost would have to be borne by industrial firms, at the cost of their margins. In some sectors – particularly textiles and paper - increased prices would increase the risk of import substitution from first producing in countries without carbon taxes.

We have not sought to quantify the transition risk relating to Colombian industry beyond liquid fuels and coke. This would require a more detailed analysis of the size, specification, and thermal efficiency both of existing and potential replacement facilities to understand the size of any potential efficiency gains (which were material in the context of transport). An analysis of this, as well as an analysis of the competitive positioning of the firms within their markets, will be important to gain an understanding both of what carbon price would be required to incentivise fuel switching and what additional costs the firms and their customers could bear.

5.5.1.3. Colombia's climate transition risk concentrations: a summary

Across the analysis set out in this paper, we have assessed climate transition risk across the majority of non-AFOLU real economy sectors. The magnitude of the risk, the timing and distribution of the risk among regions and economic groups are all important considerations for government in relation to its response to the risk. A summary of the results is set out below.

This analysis suggests that the Colombian government should prioritise actions in relation to climate transition risk in the export thermal coal mining industry, the domestic thermal coal mining industry, coal fired power plants, crude oil exploration and production in the current administration. This means taking proactive action to prepare for the potential decline in the economic viability of these sectors, so risk does not fall on those with limited capacity to bear it. However, as we argue in section 5.5, this does not mean that government should take a slow (or "cautious") approach to decarbonisation planning in other real economy sectors.

The question of what proactive action might look like is one that has connotations beyond the scope of this study. One, potentially expensive, option would be to provide financial or other support (or "bailout") to firms in sectors facing downside risk, in the hope that investors will reinvest and create new jobs in other industries in Colombia. However, there would no guarantee of them doing so, especially in the case of firms with limited commitment or other businesses in Colombia. Doing this systematically could create moral hazard and a self-fulfilling prophecy with investors seeking to de-risk their positions by pushing risk onto the government.

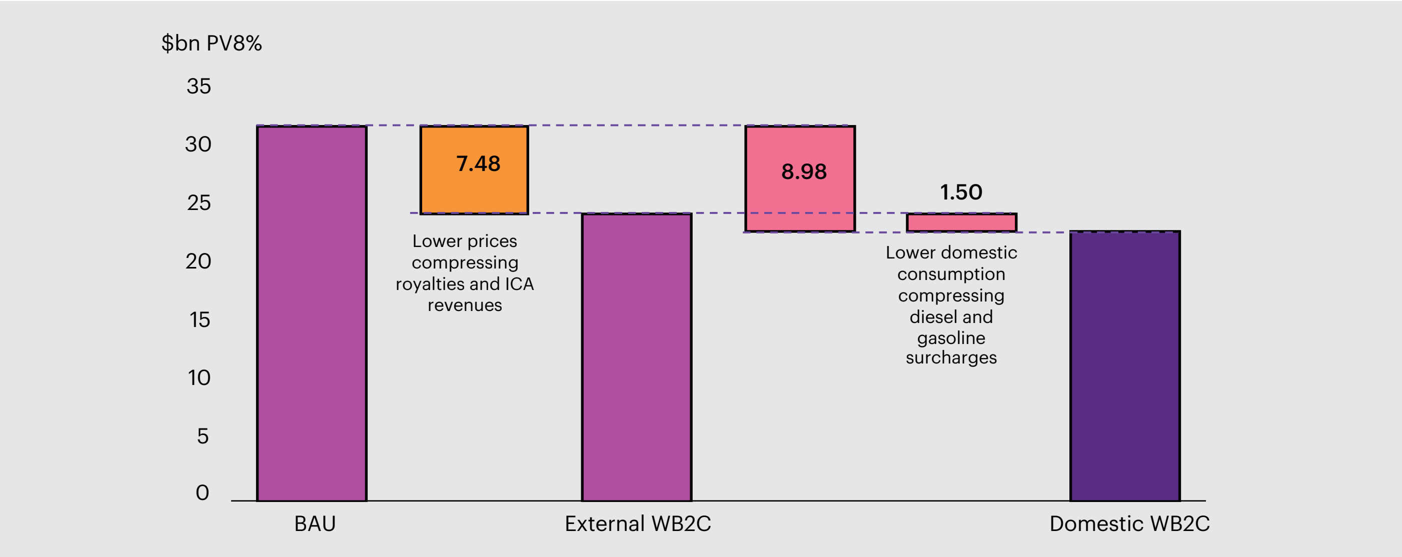
In contrast to investors, workers, communities, and local governments are likely to have less flexibility, fewer options and seem therefore to be a clearer potential target for support. For example, local governments could face downside risk relating to the oil and gas sector from both external and domestic transitions, with falling sales affecting ICA revenues and fuel surcharge collections (the majority of which are allocated to local government), as illustrated in figure 48. Certain local governments will also face exposure in the power sector via utility companies that they own, including EPM (Medellín) and Emcali (Cali).

Table 74: **Summary of Colombia's climate transition risk exposure by sector**

Sector	External transition risk exposure?	Domestic transition risk exposure?	Timing of risk crystallisation
Thermal coal mining (exports)	Downside (very high)	-	Sharp decline: late 2020s/ early 2030s
Thermal coal mining (domestic)	Downside (limited) Norte de Santander most affected	Downside (high)	More gradual decline starting in 2020s (power). Long term future dependent on viability of CCUS in industry.
Coal power	Downside (low) from lower gas prices and lower power prices	Downside (high)	2020s to early 2030s
Crude oil exploration and production	Downside (medium) Very low for existing assets, high for new ones	-	Late 2020s to 2030s
Natural gas exploration and production	Downside (low)	Downside (medium)	Starting in 2030s. Long term future dependent on viability of CCUS in industry
Oil refineries	Downside (medium)	Downside (low)	2030s
Natural gas power	-	Downside (medium) in short run (lower average wholesale prices). Downside (high) in long run (displacement by clean flexible and firm generation)	Starting in 2030s
Hydropower	Downside (low) from lower gas prices and lower power prices	Run of river: Downside (medium) in short run (lower average wholesale prices). Reservoir: Upside (size depends on future electricity market design)	Starting in 2030s
Metallurgical coal mining and coke production	Downside (high)	Downside (medium)	Starting in 2030s
Iron and steel	Upside (medium) assuming Colombia decarbonises slowly	Downside for Paz del Rio Uncertain for other primary steel production[418]. Neutral-to-positive for recycled steel production	Starting in 2030s
Cement / concrete	-	Neutral to limited downside	Starting in late 2030s
Other direct heat (brick, lime, glass)	-	Uncertain	Uncertain
Food (sugar refining)	-	Uncertain	Uncertain
Textiles	-	Uncertain	Uncertain
Pulp and paper	-	Uncertain	Uncertain

418. Aircraft leasing companies are increasingly dominant owners of planes within the global aviation industries (https://www.reuters.com/business/aerospace-defense/leasing-firms-now-buy-more-planes-than-ailing-airlines-industry-pioneer-2021-09-20/). The UK has pioneered structured financings of rolling stock fleets (source: https://www.porterbrook.co.uk/)

Figure 48: **Local government exposure to climate transition risk (external and domestic) in the oil and gas value chains**



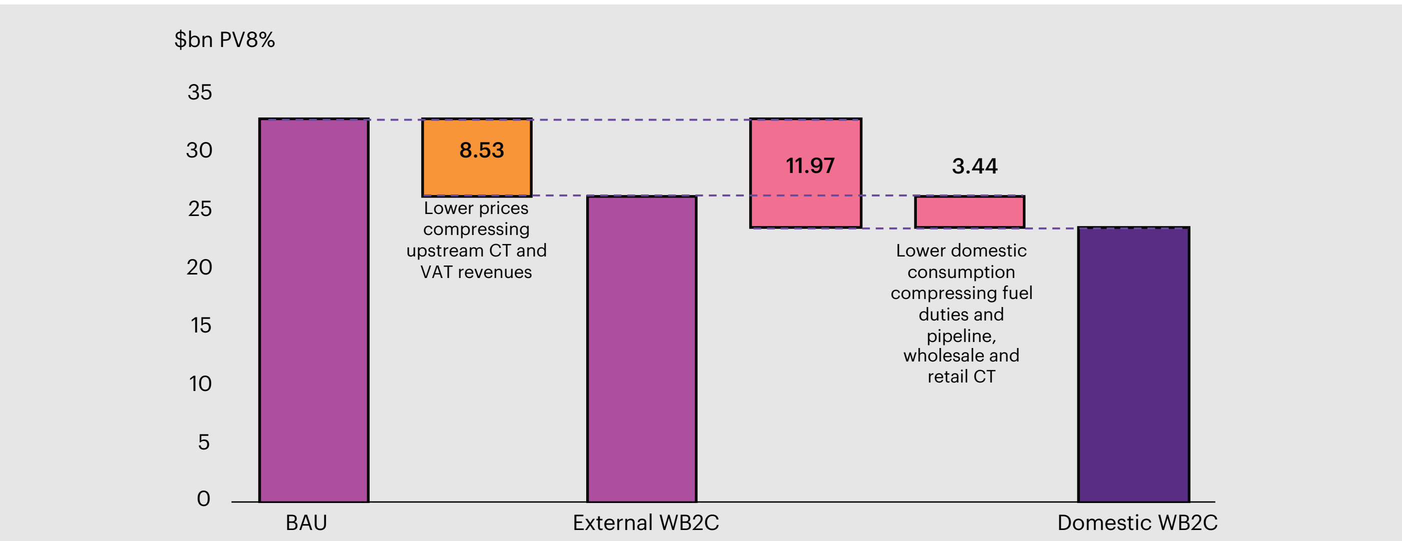
When considering proactive action to support those facing risk concentrations, national government should consider its ability to take on these incremental risks (see figure 51), given the scale of transition risk already identified in this report that could accrue to the national public balance sheet. In chapter 4, we highlighted the materiality of the impact of external transition risk on fiscal revenue and the value of state-owned enterprises, such as Ecopetrol and the risk that national government could inadvertently take on other parties' transition risks.

Domestic transition efforts will affect public finances in a different way. We are aware that national government officials are considering policies that could raise additional revenues (such as carbon pricing). At the same time, an accelerated move away from oil and gas consumption would put additional pressure on existing sources of revenue at precisely the time when government might consider increasing spending to incentivise the development of new low carbon industries (sections 5.3 and 5.4) and helping to mitigate concentrated transition risks in the country.

This illustrates the importance of calibrating domestic transition policy carefully with an understanding of external transition risk.

At the level of the macroeconomy, climate transition risk also clearly poses a challenge for the long-term sustainability of Colombia's economic model. While the recommendations set out in sections 5.3 and 5.4 of this chapter give some hope of offsetting climate transition in the medium term by diversifying exports and reducing consumption of fossil fuels, Colombia still faces the potential of persistent decline in that external balance and in mining and fossil fuel GDP during this decade. This could create challenges for both economic growth and public indebtedness, risking further sovereign credit rating downgrades with knock-on impacts for financial stability and future economic growth, as explored in chapter 4. Even if this does not happen, the transition to an economy with structurally lower hydrocarbon rents may necessitate the development of an alternative model of funding public services as a structural decline in regalías diminishes a material source of value centralised and currently redistributed to local governments.

Figure 49: **National government revenues and transition risk from the oil and gas value chains**



5.5.2 Options for mitigating transition downsides

The risks highlighted in section 5.4.1. are ones that, according to our analysis, do not seem naturally offset (in either time, location, or economic group) by the growth of new industries or Colombian deep decarbonisation. Many of those facing concentrated exposures also have limited recourse to another important risk management option – diversification. While firms can diversify their investments and the national government can act to incentivise diversification in the economy, coal mining workers or local governments have few opportunities to diversify. These parties will need targeted risk mitigation support, for which we list options in the table below, based on strategies undertaken in other countries.

The investigation of any of these options in detail has been outside of the scope of this study. However, we would recommend national government to accelerate the investigation of risk-bearing capacity and risk-mitigation options during this government. This should ideally include not only national government personnel but also local government, civil society and, where relevant, representatives of workers and firms facing downside risk. This could result in a Hoja de Ruta for transition funding packages that also draws on expertise from international precedents.

Table 75: **Summary of Colombia's climate transition risk concentrations**

Group facing concentrated risk	Impact of transition risk	Potential transition risk mitigation options
Workers in assets and industries facing downside risk	Loss of income. Potential decline in the value of skills, know-how	Support to find alternative employment in other mining industries (for example, copper) Support and funding for retraining and relocation within Colombia Guarantees of pension payments and potential early retirement for older workers Time-limited zero- or low-cost funding to support workers as they seek new employment Additional state support for those falling into long-term unemployment
Local governments	Loss of income. Loss of adjacent economic activity. Higher demand on services. Reducing capacity to provide services as creditworthiness declines	Additional government transfers Additional debt / revenue raising powers Transition insurance or other contingent financing
Heavily indebted, undiversified firms (such as independent oil and gas producers; supply chain firms for those analysed in this report)	Lower revenues, higher costs. Declining creditworthiness and potential credit defaults and/or bankruptcy	Short-term tax holidays / waivers Direct government support (equity stakes) Transition insurance or other contingent financing

5.5.2.1. Risk mitigation funding options

Regardless of which strategy is ultimately defined, Colombian national government action to mitigate climate transition risk ultimately will likely mean increased government spending at precisely the time when government revenues are falling because of the global transition. To deal with this challenge, national government should draw on new potential sources of revenue, while considering the possibility of tapping emerging new climate-related funding sources.

5.5.2.1.1. Capturing the gains from lower low carbon system costs

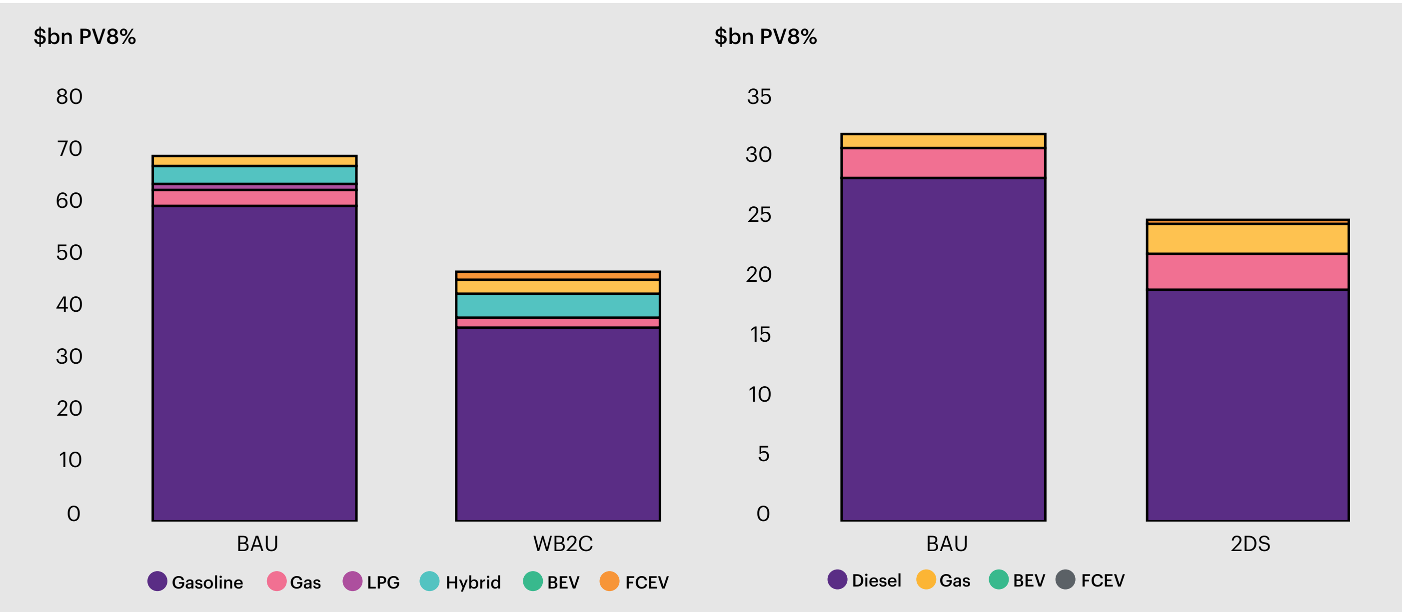
Analysis set out in this report shows that while certain Colombian firms and workers may face downside risk from the transition, Colombia would expect to gain from lower system costs in low carbon power and passenger transport systems, provided that the investments to implement that decarbonisation are structured in an efficient manner (see section 5.5). While much of this value might naturally accrue to consumers via lower prices, in practice, this is something that the national government could easily share in, via electricity and gas price subsidies and the FEPC price stabilisation system for liquid fuels.

In today's Colombian electricity sector, customers with least ability to pay receive a subsidy, financed by taxes on the electricity price for those with more ability to pay (including industrial consumers). In practice, retail distribution companies remain subject to the risk that regulated prices are not updated quickly enough to reflect changes in input costs. National government has also historically provided a small subsidy from the public budget to offset part of the impact on industrial consumers. If this subsidy system persists, we would expect to see the benefits of lower system costs in a WB2C scenario with lower system costs being recouped first by the national government (to reduce the call on the public budget) and then going to industrial customers and or/those in wealthier tariff bands, in order to reduce the cross-subsidy. In practice, we expect that this risk allocation could work differently in future, in the context of ongoing discussion about the reform of energy price subsidies and alternative mechanisms for supporting poorer groups (including basic income). Any decision about electricity price subsidies should also take into fact the importance of the electricity price paid by industrial consumers (including green hydrogen producers) and users of electric transport in the context of Colombia's low carbon transition economywide, not to mention, the competitiveness of Colombian industry.

The costs of fuelling in Colombia's transport sector would also fall in an accelerated decarbonisation scenario. The impact of a global transition exerting downward pressure on liquid fuel prices could help government to start unwinding the accumulated FEPC deficit. However, consumers would gain from the lower running costs of a switch to a more thermodynamically efficient source of energy such as electricity and the fact that electricity is subject to a much smaller tax burden than petrol or diesel. Faster uptake of both urban and rural public transport use would also help reduce fuel cost at an individual and system level.

Further research would be required to gain a more precise understanding of the distribution of the potential gains between firms investing in the low carbon transition, consumers, and government. However, with our estimate of low carbon savings in running costs

Figure 50: **Discounted fuel/energy expenditure for road users. Left: LDVS. Right: Freight.**



from light duty vehicles only running at more than $20 billion in net present value terms (2022-2050), a meaningful government share would be a potentially lucrative source of additional revenues to help manage the transition.

This value could be captured via gradual adjustments to fiscal and subsidy mechanisms that shift costs from electricity and hydrogen onto liquid fuels and which increase the amount of tax in periods of low global energy prices. The value could be "recycled" with the sectors where it arises, for example, to provide support (in the form of capital grants or low-cost financing) for accelerating the take-out up electric vehicles whose upfront costs would otherwise be prohibitive for many road-users or for supporting local governments in funding the construction of electric vehicle charging infrastructure. Capital grants, along with non-financial policies, such as vehicle scrappage schemes and blunter policies such as legislative phase-out dates for certain classes of vehicles may be crucial in spurring the growth of this sector. Part of the value could also be injected into the financial sector via state-owned development banks to support discounted lease financing offerings. Lease financing can also support the growth of fleet-based business models, drawing from the model pioneered internationally with aircraft and rail rolling stock financings[419]. The growth in market share of fleet-based business models can also have indirect benefits for transport decarbonisation by encouraging the use of and reducing the cost of ride-sharing services and in so doing, reducing the number of consumer kilometres travelled per year.

Other options for the use of these gains would be to capture them and use them to fund targeted mitigation for workers and local governments affected by transition risk downside, perhaps via a ringfenced energy transition or "just" transition fund or funds. Finally, additional government revenues from lower cost systems could, in theory, be used to help unwind accumulated tariff deficits, such as the FEPC. However, in practice, this value is unlikely to be available to help mitigate risk crystallising in the 2020s, given that the gains described in this section are most likely to arise in the 2030s.

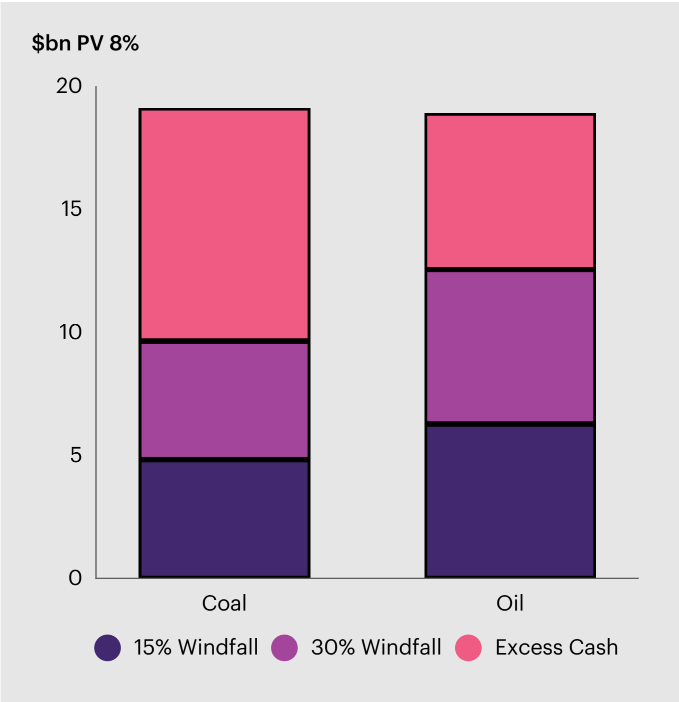
5.5.2.1.2. Capturing an additional share of revenues in high commodity price periods

Given the timing and magnitude of downside risks (very near term in some key sectors) and the more gradual payoffs of upsides, additional sources of funding will be required to help finance an economy wide transition. One additional potential source, which has been put forward by the new government as part of a new fiscal reform bill, is an exceptional or "windfall" tax on the profits of coal miners and oil and gas companies, who have benefitted significantly from sharp increases in prices as a result of the war in Ukraine[420]. This level of this tax would need to be calibrated carefully and not so onerous that it compromised the ability of those firms to invest in diversifying their portfolios towards lower carbon activities. The current tax reform proposal would tax 10% of revenue earned by exporting coal, oil, and gold exports over certain reference values.

Compared with the gains discussed in the previous section, the size of the potential short-term gains from elevated commodity prices is much harder to predict, as is an assessment of how long prices may remain elevated during the war and its aftermath.

Figure 51 provides an illustration, using the team's analysis, of the excess value (additional value that is expected to be generated above the levels of free cash flow companies would have been expecting in the absence of the war in Ukraine). This shows that an additional tax of 30% on that value could raise over $20 billion of value from crude oil and thermal coal producers if prices remained elevated for five years. This amounts to over half of total national government climate transition risk exposure as set out in chapter 4.

Figure 51: **Potential windfall tax funding**



419. "Windfall taxes" have been announced or imposed on energy producers in many parts of the world, including Germany (https://www.ft.com/content/bb58922d-2a40-4aa8-8844-9295c831fc22), Spain (https://www.reuters.com/world/europe/spanish-ruling-coalition-proposes-windfall-tax-utilities-banks-2022-07-28/) and such measures have even been endorsed by the IMF (https://www.imf.org/en/Publications/IMF-Notes/Issues/2022/08/30/Taxing-Windfall-Profits-in-the-Energy-Sector-522617)
420. See: https://ec.europa.eu/commission/presscorner/detail/cs/ip_21_5768

However, the notion of government and private investors sharing resource profits in different proportions at different price levels. Production sharing agreements (PSAs) for oil and gas resource developments are often used in developing countries to achieve that outcome, with investors typically taking a higher share of value tends in times of higher prices and profits. As the structural changes that global energy markets will undergo as the transition plays out seem likely to cause increased oil market volatility, Colombia could consider implementing a recurring but predictable increase in profit taxes in future periods of higher prices or even something approximating the "cap and collar" mechanism used in certain financial derivatives which could also partially de-risk private investor involvement in Colombian oil and gas and coal mining developments. Such a mechanism would allow Colombia to earn additional revenues in times of oil price spikes, which could be used either to compensate fuel consumers (preventing the build-up of a large FEPC tariff deficit) or more productively, funding investment incentivisation for building a deeply decarbonised Colombia and/or by creating or adding to the recommended energy transition funds mentioned above.

Either way, additional revenues of this type, which could be available in the 2020s, could be a material and flexible source of funding for climate transition risk mitigation including economic transformation. Other sources of dedicated climate-, ESG- or energy transition funding from developed markets may be more predictably available but could come with conditions that constrain Colombia's ability to use the funds.

5.5.2.1.3. Drawing on emerging new climate-conscious international sources of capital

Along with Chile, Colombia has led the way in Latin America in taking advantage of the appetite from investors for more sustainable investment opportunities. Colombia's maiden local market (TES) green bond issuance in September 2021 was named Environmental Finance's "Green Bond of the Year – Sovereign". In April 2022, Colombia launched Latin America's first green taxonomy, designed to help direct private and public spend towards "green" projects and in May 2022, the government launched a Colombia branch of the Bloomberg-funded Climate Finance Leadership Initiative designed to help stimulate the flow of private capital into climate-related projects. These initiatives are likely to help scale interest in local and international capital in financing large infrastructure projects that will be key to Colombia's domestic transition including wind and solar farms, hydrogen production and electricity grids.

Labelled capital markets issuances and those compliant with the green taxonomy may be well placed to support low-risk investments in established technologies and blended finance (with national and international sources of credit enhancement) can help scale-up investment in nascent technologies. However, a nascent source of government-to-government financing may be better suited to financing structural transformation. Just Energy Transition Partnerships (JETPs) may be a more effective source of capital to help Colombia mitigate climate transition risk. South Africa is a pioneer for the JETP movement, after the announcement at COP26 of the Just Energy Transition Partnership, under which a club of the European Union, the UK, France, Germany, and the USA plan to provide $8.5 billion, via a mixture of "grants, concessional loans and investments and risk sharing instruments"[421]. Other announcements were made about similar arrangements being considered in Indonesia, Vietnam, and India[422]. If Colombia were to commit to a mixture of phase-out (for example, of coal or coal power) and phase-up of low carbon industries, this may allow the government to unlock significant international resources and support.

This sort of funding could be well suited to help Colombia mitigate transition risk that cannot be mitigated using any of the strategies referred to in this chapter and analysis of the sort presented in this report would be useful in helping Colombia size and structure any request for support. JETP funding could include a mixture of commercial loans, concessional loans, contingent capital (such as insurance and hedging facilities) and grants.

Finally, for areas identified in this report, where Colombia's transition pathways remain extremely uncertain – for example, in major industrial coal consumers in brickmaking, lime production, glassmaking, sugar refining, textiles and pulp and paper industries – international philanthropic funds are likely to be available to support technoeconomic studies on these issues. A model like the Energy Transitions Commission[423] may be an appropriate one to help bring together and synthesise local and international expertise to develop evidence-based pathways and solutions.

421. Much work on JETP transactions in Asia have been led by the Asian Development Bank: https://www.reuters.com/business/sustainable-business/adb-sets-plan-retire-coal-fired-power-plants-philippines-indonesia-2021-11-03/
422. Source: https://www.energy-transitions.org/
423. Source: WTW and UniAndes analysis.

5.6 Conclusion

The range of public discourse about the dangers of the in-coming administration's energy policies has been instructive for these authors, with long-run decline in Colombia's hydrocarbon resources being assumed to lead to economic ruin. In some ways, the findings of this study may add to the urgency for Colombian policymakers to consider the implications of a sooner-than-expected decline in extractive sectors, resulting both from a global transition in line with the Paris Agreement and Colombian policy implemented in pursuit of E2050 goals. However, this chapter has shown while that climate transition risk (coupled with the challenges of declining hydrocarbon reserves) could be destabilising for Colombia if not taken seriously by policymakers, it is manageable if policymakers start to incorporate these issues into their planning.

This means that BAU policymaking and investments favouring natural gas (with the hope that successful deployment of carbon capture and storage may provide long term mitigation of emissions from natural gas) may ultimately be a riskier long-term strategy for Colombia than an accelerated domestic transition. Most future potential investments in long-life coal, oil, and gas deposits and infrastructure that cannot be recouped or diversified in the next 15-20 years are likely to add to the $88 billion of downside risk identified here. This report has also shown that successful management of climate transition risk requires very close attention to timing and distribution. If Colombia does not take urgent action to speed up the deployment of low-carbon energy sources (such as electricity and hydrogen) and related infrastructure and the simulation of demand (and funding for investment) in transport and industry, meeting the E2050 goals could be more costly than it needs to be, and the transition could be "disorderly". Even if Colombia is successful in accelerating the scale up of "clean", if significant climate transition risk is left with workers, communities, and local governments, economic dislocation from the global transition could still be significant. If the risks, costs, and benefits of Colombian deep decarbonisation are not perceived to be shared fairly, this could impact social consent for the required structural changes.

The important of embedding of climate transition risk scenario considerations (and doing so in a transparent fashion) into policymaking, regulation, and capital allocation cannot be understated. Without this Colombian policymakers, firms, investors, and civil society may significantly underestimate the opportunity costs of a slow and "cautious" decarbonisation path. Across the world, a key lesson from the global energy transition to-date has been that smart government intervention and support of low-carbon technologies across power, transport, and industry (and the minerals and infrastructure that enable them) is required to spur deployment and reduce costs. As highlighted in this chapter, Colombia has many such potential opportunities (in extractive and non-extractive sectors) and has taken promising steps in recent years to realise them. However, just as the trajectory of global greenhouse gas emissions reductions needs to accelerate to limit global warming in line with the Paris Agreement, so the need for accelerated investment in low carbon technologies is creating fierce competition. Colombia may lose out on significant opportunities if it moves too slowly or faces economic dislocation because it does not effectively manage external climate transition risk.

If Colombia manages its risks and pursues its opportunities effectively, the country may look forward to a prolonged period of economic stability, even if a disorderly global transition provokes increasing volatility on global markets. Long term, reducing exposure to fossil fuels, with all the implementation challenges associated that, could be the most effective strategy for Colombia to prosper and ensure energy independence amidst increasing volatility in a changing world.

Recommendation	Recommendation for
Embed an understanding of climate transition considerations into Colombian policymaking, firm strategy, investment flows, academic research, and civil society action	
A. Building capacity in and awareness of climate transition risk issues – global and Colombia-specific	
1. Continue to procure independent advice on climate transition issues (including on climate transition risk, climate transition scenarios, low carbon technologies and approaches to repurposing fossil fuel infrastructure and rebuilding post-fossil fuel communities), drawing on both international and Colombian expertise. This advice and the research underpinning it should not be funded by real economy industries with an economic interest (downside or upside) in the design of Colombia's low carbon transition	**DNP, MME, MADS**
2. Consider setting up an independent institution (or an independent part of an existing institution) with a legal mandate to provide advice to government on transition issues.	**DNP, MME, MADS**
3. Continue to provide support in efforts to provide training to Colombian policymakers, real economy firms, financial institutions, academia, and civil society on climate transition scenarios	**DNP, MHCP, MADS, Colombian academic institutions**
4. Develop Colombia-based dedicated climate transition modelling capacity	**DNP, Colombian academic institutions**
5. Develop a comprehensive understanding of physical climate risk that is compatible with this analysis of climate transition risk. Understanding these risks better and taking action to build resilience to them would further enhance Colombia's future sustainable development prospects	**DNP, MHCP, MADS, Colombian academic institutions**
B. Use the data and analysis from this study to "stress test" current and planned policies, regulation, and investment plans	
6. Design and complete a cross-government macroeconomic and financial system stress test (building on the work already undertaken by BanRep and SFC) for a scenario with an accelerated decline of coal mining, coal power and crude oil production in the next ten years	**MHCP, DNP, BanRep, SFC**
7. Incorporate medium-term climate transition considerations into budgetary planning and assessments of public debt sustainability. Publish the results alongside budgetary documents	**MHCP**
8. Develop processes to manage climate transition risk and its potential impact on sovereign debt – hence avoiding what would otherwise likely be an increase in the cost of capital	**MHCP**
9. Develop a process for managing, monitoring and, where appropriate, provisioning against climate risk-related contingent liabilities to the public balance sheet	**MHCP, SFC, BanRep**

10. Make climate transition risk analysis a mandatory part of the due diligence process for major public investment decisions, including those by state-owned enterprises. This could help to avoid spending public money on new investments that increase Colombia's climate transition risk exposure.	**MHCP**
11. Make new licenses (or license extensions and renewals) relating to coal, oil, and gas subject to enforceable funding commitments around closure and post-closure costs. This could avoid implicit (and unbudgeted) transfers of climate transition risk from private sector firms to government.	**MME, ANH**
C. Accelerate detailed analysis in relation to support decisions around key uncertainties underlying Colombian climate policy	
12. Accelerate initial climate transition analyses for issues out of the scope of this report: CCUS – technical viability and costs	**MME, DNP**
13. Accelerate initial climate transition analyses for issues out of the scope of this report: cross-cutting AFOLU emissions mitigation and climate transition analysis	**MinAmbiente, DNP**
14. Accelerate initial climate transition analyses for issues out of the scope of this report: biofuels and biomass – including an assessment of which sectors to prioritise	**MinAmbiente, DNP**
15. Accelerate initial climate transition analyses for issues out of the scope of this report: "clean firm" generation. Conduct a review of the current electricity market regulatory framework drawing on international examples of the challenges of moving from a "capacity"- to "flexibility"-based system	**MME, DNP**
16. Develop techno-economic studies, drawing on the best international examples, on the relative costs of low carbon technology options in sugar refining, pulp and paper, textiles, and chemicals industries. Develop transition pathways for these sectors incorporating uncertainty about the future costs and availability of CCUS and circular economy strategies.	**MME, DNP, MinAmbiente, ANDI**
17. Develop a model for cross-sector infrastructure planning and investment requirements in different climate transition flows	**All, led by DNP**
18. Conduct research into alternative Colombian economic models with significantly reduced dependence on fossil fuel rents	**MHCP, BanRep**
D. Enhance public transparency about the data, scenarios, and detailed policy priorities underpinning Colombia's long-term deep decarbonisation plans	
19. Develop publicly available common scenarios and data to be used for "stress testing" and scenario analysis across public sector, financial institutions, and private real economy corporates	**DNP, MHCP, SFC, BanRep**
20. Develop and consult on a policy and regulatory toolkit of options that could be used by public bodies to accelerate a Colombian transition. These could include regulatory changes (for example, including an emissions performance standard for new power generation); legislative phase-out dates (for example, for unabated coal-fired power generation); outright bans, including those with a phase-in date (such as in relation to internal combustion engine vehicles; fiscal incentives and disincentives (such as carbon pricing); provision of low cost public or public-backed financing for low carbon developments (for example, through public development banks) and wholesale market design changes (for example, in the electricity system)	**DNP, MME, MHCP, MADS**

E. Facilitate an orderly shift of capital flows from sectors expected to face decline in a transition to those expected to be resilient to or benefiting from a transition	
21. Accelerate requirements and guidance for transition plans and reporting for thermal power generators (including information about coal and gas procurement contracts), coal miners and oil and gas production companies.	**MME, MHCP**
22. Use (and potentially extend) the green taxonomy as a means to direct public and private spending towards transition opportunities and mitigation of transition risks	**DNP, MinAmbiente, MHCP**
23. Accelerate requirements and guidance for climate risk management and reporting in Colombian financial institutions including public financial institutions	**SFC**
24. Consider the applicability for the Colombian context of financial regulatory options for mitigating climate risks being developed by the world's central banks and financial regulators, including differential risk weightings for assets and asset classes facing climate risk exposure; differential capital requirements for firms based on the strength of their climate risk management practice and the application of systemic risk capital buffers	**SFC, BanRep**
Prioritise growth of economic sectors with large-scale export potential	
25. Pursue "no regrets" diversification of the Colombian export basket by growing sectors (such as agricultural exports). Consider a range of factors when considering the diversification potential or new or growth economic sectors including potential to scale quickly; potential to bring in foreign currency revenues; potential to diversify the fiscal base; exposure to climate transition risk and physical climate risk	**DNP, ANDI**
26. Design and implement reforms to freight infrastructure, the electricity system and electricity tariffs to ensure a low cost and reliable system that supports Colombia's competitiveness as an exporter of industrial goods	**MME, ANDI**
27. Accelerate diversification of mining exports towards "transition metals", such as copper, subject to thorough assessments of environmental risk. Assess potential investments metal refining / smelting capacity considering climate transition risk.	**MME, ANM, DNP**
28. Conduct research (or join international research efforts) on potential technologies to convert the nickel ores produced in Colombia to battery grade	**MME, DNP**
29. Develop pilot projects relating to the production of synthetic air fuel (SAF) and low carbon marine fuel at Colombian oil refineries	**MME, DNP**
30. Consider the development of a medium-term economy-wide industrial strategy to ensure that Colombia is well prepared to benefit in a deeply decarbonised world	**DNP, MHCP, ANDI**
Prioritise growth of economic sectors with large-scale export potential	
31. Consider the potential for using transition upsides (for example, in jobs, profits and taxes) to offset transition downsides – in both location and timing	**DNP, MME**
32. Consider and cost alternative accelerated transport decarbonisation scenarios, incorporating the benefits to Colombia from the reduction of future oil and liquid fuel imports	**MinTransporte, DNP, MHCP**
33. Consider and cost alternative accelerated power generation and industrial decarbonisation, incorporating the benefits to Colombia from the reduction of future natural gas imports	**MME, DNP, MHCP**

34. Prioritise modal shifts in both passenger and freight transport to reduce total energy demand in the transport sector	**MinTransporte, MHCP, local governments**
35. Integrating external considerations into decisions around domestic pathways (in particular, around the role of hydrogen), considering the possibilities for domestic demand to incubate export-calibre industries	**DNP**
36. Co-ordinated planning across government, industry, finance, and civil society can help to ensure that infrastructure constraints and inter-sectoral trade-offs are appropriately incorporated into planning	**DNP, MHCP**
Proactively target groups and regions with concentrated downside risk with funding and support	
Identifying climate transition risk concentrations	
37. Develop clear and transparent criteria about who will be eligible for state support in relation to climate transition risk, focussing on parties with limited financial flexibility and options to mitigate	**MHCP**
38. Be selective and transparent about which firms are considered for extraordinary ("bailout") support and the conditions under which that support is offered	**MHCP**
39. Incorporate an understanding of external climate transition risk exposure and risk-bearing capacity for firms and sectors when considering the potential costs and benefits of different domestic transition mechanisms (such as carbon pricing)	**MHCP, DNP**
Options for mitigating climate transition downside	
40. Develop roadmap for designing transition funding and support packages for workers, and communities at risk, drawing on learnings from international and Colombian precedent	**DNP, MHCP**
41. Develop roadmap for short-term support and long-term changes to local government funding mechanisms to adapt to a structural decline in fossil fuel rents	**DNP, MHCP**
42. Set up regional transition commissions co-chaired by national and local governments and including the explicit involvement of civil society organisations	**DNP, MinAmbiente**
43. Use fiscal and subsidy mechanisms to capture a share of gains accruing to firms and consumers from lower electricity and transport system costs in a lower carbon Colombia	**MHCP**
44. Design and implement a new fiscal mechanism to capture "excess" profits from coal and oil industries - to be used to finance transition initiatives across the economy. Consider a mechanism with longevity beyond the war in Ukraine to capture a share of future commodity price spikes as part of a global transition	**MHCP, DNP**
45. Access internationally available sources of Just Energy Transition Partnership (JETP) funding, to help fund structural change and the potentially severe socio-economic impacts of the decline of key export industries	**MHCP, DNP**
46. Access internationally available sources of philanthropic funding, to be used to invest in and lower the cost of capital for new technologies, deal with concentrated areas of transition risk to prevent systemic issues and help fund training costs to build the technical acumen of public servants	**MHCP, DNP**

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