GREENING CONSTRUCTION

The Role of Carbon Pricing

CARBON PRICING LEADERSHIP COALITION

International Finance Corporation
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A unique initiative, the Carbon Pricing Leadership Coalition (CPLC) brings together leaders from national and sub-national governments, the private sector, academia, and civil society with the goal of putting in place effective carbon pricing policies that maintain competitiveness, create jobs, encourage innovation, and deliver meaningful emissions reductions. The Coalition drives action through knowledge sharing, targeted technical analysis and public-private dialogues that guide successful carbon pricing policy adoption and accelerate implementation. The Coalition encourages private sector climate leadership through sector-specific task teams, including for the construction industry and the banking sector.

The Coalition was officially launched at COP21 in Paris in December 2015. As of 2018, CPLC comprises 32 national and sub-national government partners, 150 private sector partners from a range of regions and sectors, and 67 strategic partners representing NGOs, business organizations, and universities. More information: https://www.carbonpricingleadership.org/

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IFC, a member of the World Bank Group, creates opportunity for people to escape poverty and improve their lives. We foster sustainable economic growth in developing countries by supporting private sector development, mobilizing private capital, and providing advisory and risk mitigation services to businesses and governments. This report was commissioned by the Carbon Pricing Leadership Coalition (CPLC) through IFC's Climate Business Department. The CPLC Secretariat is administered by the World Bank Group.

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Acronyms

AKH	Awash-Kombolcha/Hara Gebeya Railway
BRICS	Brazil, Russia, India, China, and South Africa
CPLC	Carbon Pricing Leadership Coalition
CPM	Carbon pricing mechanism
CVC	Construction value chain
DBB	Design-Bid-Build
DBFOM	Design-Build-Finance-Operate-Maintain
ERC	Emissions reduction credit
ETS	Emissions trading system
EU	European Union
ICE	Inventory of Carbon and Energy
IEA	International Energy Agency
IFC	International Finance Corporation
LEED	Leadership in Energy and Environmental Design
NDCs	Nationally Determined Contributions

Foreword

By 2050, 70 percent of the global population is expected to reside and work in cities, where there is a concentration of people, assets, financing, and opportunities. In parallel, 60 percent of the area expected to be urban by 2050 remains to be built, signifying the large scale of construction activity that the world will see in the decades leading up to then. Much of this growth will be in emerging markets.

Since so much of the urban area expected to exist in the coming decades is yet to be built, there is an opportunity for cities to leapfrog historic urbanization approaches and divert scare resources to low-carbon, resilient, efficient construction, and avoid the pitfalls of locking in high-carbon infrastructure in their urban landscape. Carbon pricing has emerged as a key tool to help construction sector companies choose lower-emission alternatives, manage carbon risk, and reduce emissions.

The private sector is already recognizing that there is a huge business opportunity associated with green construction – almost $25 trillion in emerging market cities alone to 2030 according to IFC estimates – and is approaching sustainable construction in a variety of ways. Companies across the construction value chain are using internal voluntary carbon pricing as well as signals from external carbon regulations, including taxes and emissions trading systems, to incentivize low-carbon decision-making in their own operations. Their broad range of interests in applying carbon pricing include using it as an incentive for individual business units to reduce their emissions, developing low-carbon construction material and other products, and engaging with their supply chains to encourage the use of low-carbon and sustainable alternatives, to name a few.

While these individual initiatives are essential and commendable, the efforts of construction sector companies to reduce the industry's carbon emissions can be made significantly more effective by working in a collaborative manner. This last finding is a key takeaway from this report – that companies along the construction sector need to work together and with other stakeholders, such as contracting authorities, suppliers, and consumers, to align approaches to carbon pricing and to sustainability more broadly.

By bringing together the various companies and other stakeholders along the construction value chain for this work, the Carbon Pricing Leadership Coalition is helping drive this agenda. The goal is for all these different stakeholders and initiatives to come together and work with governments to deploy well-designed carbon policies that will help reduce the construction industry's total emissions and meet climate targets. IFC stands ready to explore the development of such an integrated approach, and work with its clients and partners, both within the CPLC and outside, to design and implement it in the most effective manner. We are also working with stakeholders such as industry associations and construction sector companies to ensure the inclusion of all perspectives in this effort.

The construction industry already accounts for between 25 and 40 percent of global carbon emissions, and it is imperative that the footprint of this expected construction is managed if we are to meet the goals of the Paris Agreement and restrict the rise in temperatures to less than 1.5˚ Celsius. We must act to ensure that all this forthcoming construction is built in a sustainable manner and recognize the role of the private sector in achieving this as well as the business opportunity associated with green construction.

Alzbeta Klein
Director, Climate Business Department, IFC

EXECUTIVE SUMMARY

This report examines how to design effective carbon pricing mechanisms (CPMs) for the construction industry. As the world's largest consumer of raw materials, it accounts for a significant proportion of final energy demand and is responsible for 25 percent to 40 percent of global carbon-related emissions.[1]

Demographic trends underline the need for the construction industry to do more to address its contribution to climate change. The world's population is predicted to reach nearly 10 billion by 2050, with the majority expected to live in urban areas.[2] This will increase demand for buildings and infrastructure; some estimates suggest that 75 percent of the infrastructure we will need by 2050 must still be built.[3]

Putting a price on carbon can be an effective way for governments and organizations to plan for a low-carbon future. Applying a cost to emissions encourages sectors and supply chains to alter behavior in favor of lower-carbon choices. However, to date, CPMs have yet to achieve their potential when it comes to driving behavior change in construction.

The construction value chain (CVC) is a complex mix of life-cycle stages, delivery models, and stakeholders. Large projects with long life cycles and multiple actors can be highly fragmented; accountability or incentives to consider climate change impacts are often lacking. These constraints make the application of CPMs to construction particularly challenging.

This study explores how CPMs can be designed better to more effectively account for emissions from the CVC. To date, carbon pricing has tended to apply to carbon-intensive production activities. In the CVC, this commonly includes raw material extraction, product manufacture, and energy generation. However, this is ineffective at influencing construction design, where carbon emissions are locked in for the duration of an asset's life.

The study used scenario modeling of four case studies to examine the impacts of CPMs on different life-cycle stages, asset classes, construction delivery methods, and market contexts. The strengths and deficiencies of each CPM were analyzed, and ideas for refinement and improvement were explored.

The study findings suggest that there is no single fix. If carbon prices were increased to "midpoint" levels of \$25/tCO_2e used for this analysis (with a lower limit of \$10/tCO_2e and an upper limit of \$53/tCO_2e), then project costs could potentially change the behavior of both polluters and downstream CVC actors, including clients, designers, and users. This indicates that simply raising carbon prices within existing CPMs may bring about the refocus needed to change behaviors. Whether or not this is possible in political and practical terms depends very much on the context.

Established CPMs fail to influence the CVC actors commonly associated with early stage project-making, including funders, developers, and designers. This represents a failure in the way the mechanisms are designed and function. In practice, many of these actors retain significant power and influence over a project's whole-life carbon emissions by defining material supply chain, operational, and in-use carbon emissions. To reduce total emissions over an asset's life, an effective CPM needs to influence the early stages of project-making.

One way of capturing CVC emissions more comprehensively is to include constructed assets within CPMs. Depending on the approach, this might extend in scope to include everything from the asset's embodied carbon emissions to those arising from operation and use, as well as emissions from end of life. Because CPMs are already well established around the world, expanding them to include CVC assets may be viable and acceptable to the industry and consumers.

Of the existing CPMs applied, hybrid models are likely to provide the flexibility needed to maximize the capture of emissions while reducing the impact on welfare and competitiveness. The value of this model lies in its adaptability, accommodating variances in asset class, scale, project delivery method, and market type. Hybrid models could also help to minimize price volatility, which would appeal to investors and governments.

Where existing CPMs cannot be adjusted, this study proposes a new integrated CPM for the CVC. Devised to apply to projects, the proposed CPM would use a threshold or blanket carbon price and cover the supply chain construction activities and regulated energy in use. By accounting for the whole-life carbon performance at the point of project-making, the CPM concept creates an incentive to tackle carbon at the beginning of the asset's life cycle by those charged with its design, thus cascading low-carbon objectives along the value chain.

In the development of CPMs, governments and companies must carefully weigh the potential negative impacts against the benefits, providing solutions to help those who cannot easily alter their behavior while challenging those who can through stricter targets and penalties. Schemes must engage and align with their regional and international counterparts to create a more level playing field, share learning, and minimize threats to competitiveness.

As economies in emerging markets grow and demand for infrastructure increases, significant opportunities and benefits from implementing carbon prices arise. In these locations, carbon pricing may be used to incentivize and drive the market towards low-carbon infrastructure, raise revenues that may be used to support low-carbon initiatives, and help to fulfil local and global climate commitments.

Introduction

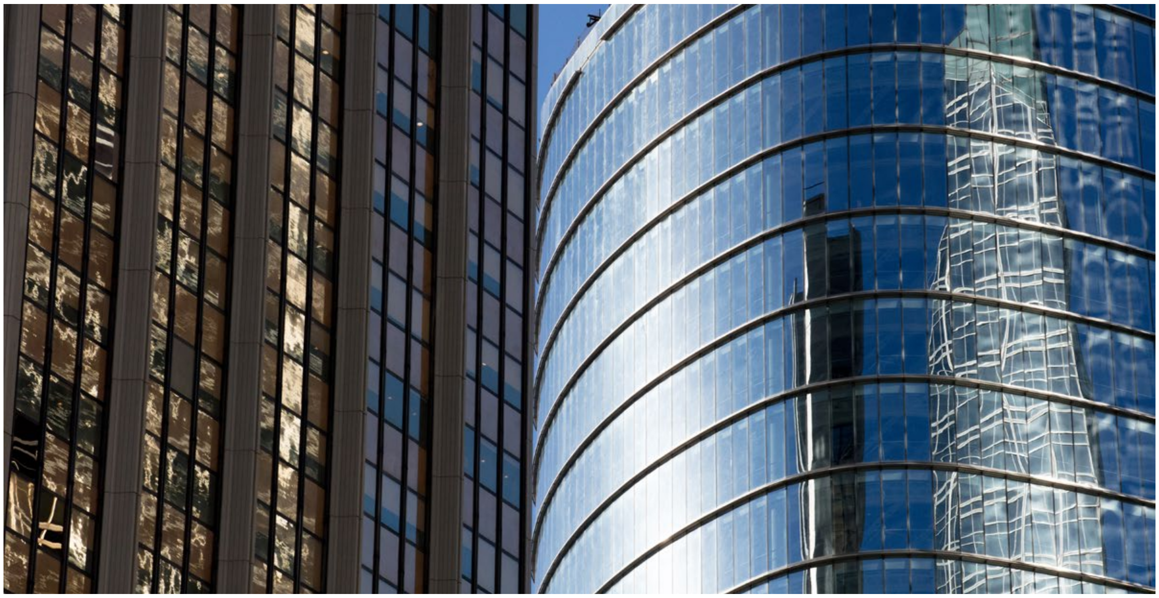
In recent years the construction industry has made notable progress to reduce its carbon emissions, developing and regulating energy efficiency requirements and implementing low-carbon technologies in buildings and along the supply chain. However,the industry remains highly energy and carbon intensive, producing 25 percent to 40 percent of the world's total carbon emissions,[4] which is likely to be compounded by the expected increase in demand for built assets.[5]

The industry recognizes that it needs to take further action if the world is to meet the Paris Agreement target of limiting global temperature rise this century to below 2°C above pre-industrial levels.[6] To this end, carbon pricing is emerging as an important tool to help the industry reduce its carbon emissions.

The scope, influence, and complexity of carbon pricing mechanisms (CPMs) is growing. CPMs are currently being used in 45 national and 25 subnational jurisdictions around the world, double the number in place a decade ago. These account for 11 $GtCO_2e$, or 20 percent of global greenhouse gases, representing a value of $81 billion.[7] The value of the fossil fuel industry is about $4.65 trillion, suggesting that there is still significant potential to be seized.[8]

TACKLING CARBON EMISSIONS IN THE BUILT ENVIRONMENT

- By 2050, six of the seven largest economies in the world could be emerging markets.[9]
- Seventy-five percent of the infrastructure that will be in place by 2050 must still be built.[10]
- The construction industry is the world's largest consumer of raw materials. It accounts for 50 percent of global steel production and more than 300 billion tons of global resource extraction.[11]
- Buildings and construction account for 36 percent of global final energy use and 39 percent of energy-related CO_2e.[12]
- Emerging economies account for nearly 60 percent of the global construction sector's total CO_2e emissions.[13]
- CO_2e emissions from buildings and construction rose by nearly 1 percent per year between 2010 and 2016, releasing 76 $GtCO_2e$ in cumulative emissions.[14]
- About 70–89 percent of construction industry greenhouse-gas emissions originate from materials, 5–15 percent from transportation, and 6–9 percent from energy consumption during construction.[15,16,17]



Carbon pricing is recognized in Article 6 of the Paris Agreement. To date, 101 countries have stated an interest in pursuing carbon pricing initiatives in their Nationally Determined Contributions (NDCs).[18] As nations, cities, and companies shift towards a lower-carbon future, CPMs offer valuable opportunities to incentivize low-carbon investment and establish clear and competitive markets for carbon.

Carbon pricing attributes a cost to the negative impacts associated with the release of greenhouse gases. This sends an economic signal to the emitter to either avoid high-emission activities or pay to continue polluting, creating incentives to change behavior throughout the supply chain. But carbon pricing is complex and its impacts are often less powerful than anticipated when applied in real-world conditions. The European Union's (EU's) emissions trading system (ETS), for example, shows that even the most sophisticated mechanism will not always achieve its objectives due to political and external economic factors, loopholes, and gamification.[19]

Although many carbon prices around the world have increased year on year (see Figure 1), their trajectories remain lower than the values needed to meet the temperature goal of the Paris Agreement. The Stern-Stiglitz High-Level Commission on Carbon Prices found that to keep global temperatures below 2°C, carbon prices would need to be between \$40 to €80/ tCO_2e by 2020 and \$50 to €100/tCO_2e by 2030.[20]

Nonetheless, CPMs are increasingly being adopted by governments and private sector organizations. Whether to incentivize low-carbon innovation, stimulate cost-effective emissions mitigation, improve production processes and industrial structures, tackle climate change, or fund broader social and environmental strategies, the adoption of carbon pricing is growing.[21] To date, carbon pricing has tended to apply to carbon-intensive production activities. In the construction value chain (CVC), this includes raw material extraction, product manufacture, and energy generation. While this has been successful up to a point, this approach is ineffective at influencing construction design, where carbon emissions are locked in for the duration of an asset's life.

To address this issue, some jurisdictions are experimenting with applying CPMs at the point of carbon "consumption" (for example, Japan is applying a CPM to retail electricity). In the CVC, this approach has the potential to more

successfully address emissions associated with design choices and asset performance in use.

This study examines how existing CPMs can be adapted to more successfully lower whole-life carbon emissions (all the emission sources associated with constructing and using a building over its life). Where this is not practical, the study proposes adopting an integrated CVC CPM that can be applied to both buildings and infrastructure.

Section 2 (Carbon Pricing in the Construction Value Chain) of the paper examines the construction industry setting, including CVC formation, actors, and life-cycle stages. It also reviews six established CPMs.

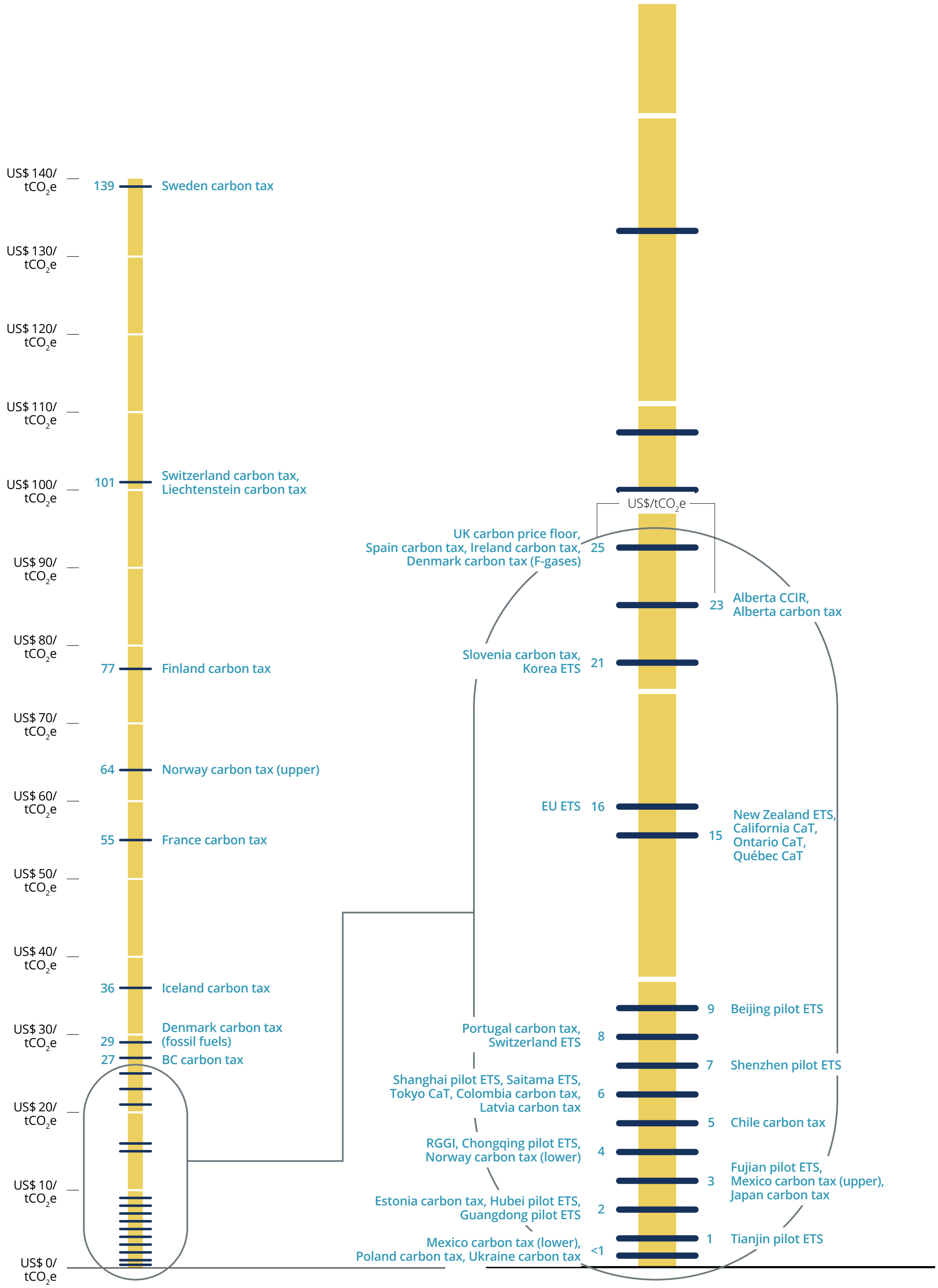
Section 3 (Case Studies) sets out the case study scenario and modeling work that has been undertaken to explore the impact of CPMs.

Section 4 (Applying Existing Mechanisms to the Construction Value Chain) provides a detailed assessment and discussion of how established CPMs might be refined to better capture and influence carbon emissions across the CVC.

Section 5 (Developing an Integrated Carbon Pricing Mechanism for the Construction Value Chain) outlines the concept for an integrated CVC CPM as an alternative model to consistently influence carbon emissions across the CVC for both the building and infrastructure construction industries.

Finally, Section 6 (Moving Forward) discusses next steps and additional research needs.[22]

FIGURE 1: **GLOBAL CARBON PRICES IN 2017/18 RANGED FROM UNDER $10 TO OVER $140/TCO₂.**[24]



Carbon Pricing in the Construction Value Chain

The construction industry setting

THE CVC

The CVC is complex, consisting of interlinked and interdependent processes and actors. Large projects with long life cycles and multiple actors often operate independently, meaning that actors along the value chain are not always accountable for or incentivized to consider how their activities affect other parts of the system (for example, designers do not commonly remain accountable for how much energy and carbon a building may use in operation).

Carbon pricing presents an inherent challenge to the construction industry as many of the products and services it offers are energy and carbon intensive and are therefore costlier if emissions are priced. Despite this, many organizations have successfully implemented internal CPMs, and many more are subject to

KEY MESSAGES

- Although the construction industry is taking action to reduce carbon emissions, carbon pricing is a relatively unexplored tool. This is largely due to the nature and structure of the industry, which is complex, fragmented, and carbon intensive. Carbon pricing presents an opportunity to make the industry more sustainable.
- This report uses a broad conception of the CVC, addressing all carbon-emitting activities at all life-cycle stages, from design through to construction, use, operation, and end of life.
- This study examines six CPMs identified through a comprehensive literature review: Internal carbon pricing, emissions reduction credit schemes, ETS, hybrid schemes, carbon taxes, and command and control mechanisms. Their functioning, strengths, and weaknesses are assessed in this section.
- A CPM influence heatmap is used to compare the influence on carbon reduction each of these CPMs has in relation to the stages of the CVC and the actors involved at those stages.

regulatory ETS and carbon taxes. Thus, with some adjustment, there are more opportunities to overcome barriers to applying CPMs along the CVC.

THE STRUCTURE OF THE CVC

Although there is no standard industry definition of what is included within the CVC, traditional interpretations have tended to include raw material production and supply, product manufacture, and construction works. When it comes to considering carbon emissions, this definition is inadequate as it does not capture all the value chain actors who have control and influence over carbon emissions or all the life-cycle stages where carbon emissions occur.

This leads to two inherent challenges. First, if all relevant actors are not included and targeted in the industry drive to cut carbon emissions, it will be more difficult to ensure behavior changes throughout the value chain. Second, if life-cycle stages that are responsible for significant sources of carbon emissions (that is, the use of a building or an infrastructure asset) are ignored by the decision-making or regulatory frameworks used to bring about emissions cuts, the outcomes will be less successful.

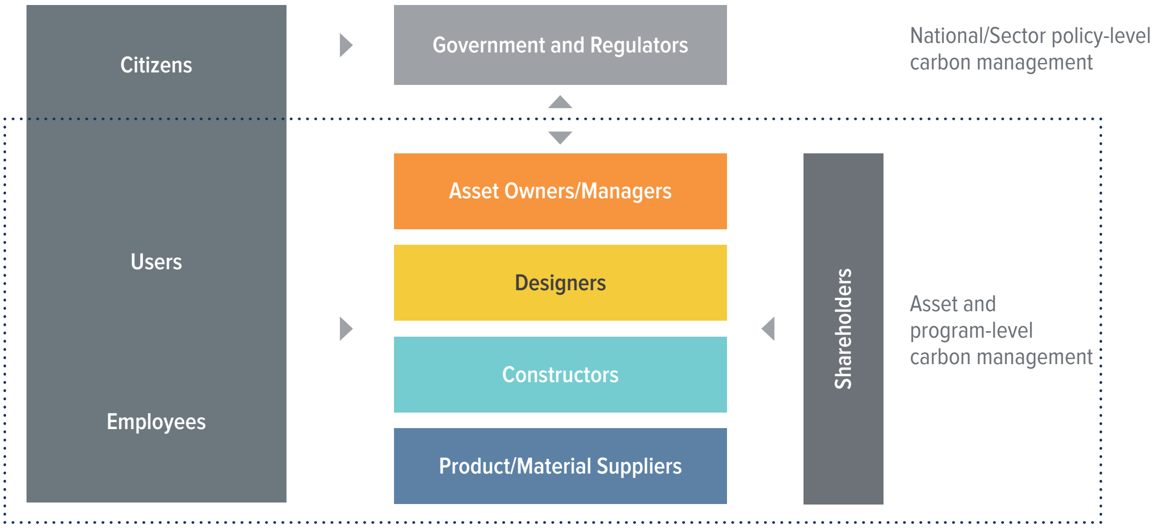
To address these constraints, this study uses a broader definition of the CVC based on BS EN 15804 on Sustainability of Construction Works,[23] and adapted by PAS2080 Carbon Management in Infrastructure.[24] This broader definition is presented in Figure 2, which shows the scope of actors responsible for carbon management in infrastructure and buildings, and Figure 3, which illustrates the life-cycle stages relevant to carbon emissions sources.

ACTORS IN THE CVC

Many diverse actors operate in the CVC. The relationship between them is complex and changes from project to project. The following actors are usually involved in a construction project:

- **Investors and shareholders** fund the development of an asset.
- **Developers** may fund, construct, or own and manage an asset for profit.

FIGURE 2: **CVC ACTORS RESPONSIBLE FOR CARBON MANAGEMENT (ADAPTED FROM PAS2080).**[82]



- **Designers** develop the design of the asset that is to be constructed or maintained.
- **Constructors** undertake work to build, maintain, or disassemble a constructed asset.
- **Product/material suppliers** extract, manufacture, or produce materials or products for construction or maintenance of an asset.
- **Asset owners/managers** manage and may be responsible for providing, operating, and maintaining assets.
- **Users** use a constructed asset and the services it provides during operation.
- **Demolition contractors/waste management** demolish, process materials arising, and dispose of waste.

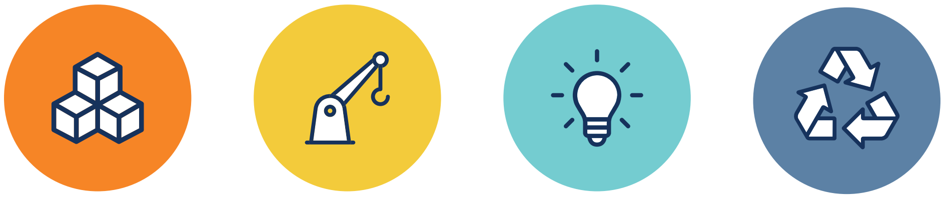
PROJECT DELIVERY METHODS

The CVC collaborates to deliver projects in various ways. There are different risks, strengths, and weaknesses associated with each approach. Figure 4 shows some of the most common project delivery methods. Their position on the matrix indicates the level of integration, and the extent to which the project is directly financed by the owner or client.[25]

The delivery method applied is usually chosen based on project size, budget, client preference, and program. The way a project is delivered may influence how carbon may be reduced over the life of the project or asset. For example, the contractor in a traditional DBB segmented model has little influence over the design of a project and no incentive to maximize carbon reduction. Conversely, in an integrated model such as design, build, finance, operate, maintain (DBFOM), each party (designer, builder, investor, operator, and manager) can be incentivized to maximize carbon reduction at every stage to ensure the overall project is delivered most efficiently.

The financing of a project will also influence how and whether carbon emissions are reduced. For example, an owner who directly finances a project may choose to prioritize carbon reduction and impose targets that contractors, operators, and managers must meet. In contrast, an owner who does not finance

FIGURE 3: IN THE CVC, ACTIVITIES ARE CARRIED OUT ACROSS FOUR MAIN LIFE-CYCLE STAGES.[83]



PRODUCT

- Design
- Raw material supply
- Transport
- Manufacturing

CONSTRUCTION

- Transport
- Construction
- Installation

USE

- Use
- Maintenance
- Repair
- Refurbishment
- Replacement
- Operational energy
- User utilization of infrastructure

END OF LIFE

- Deconstruction
- Transport
- Waste processing
- Disposal

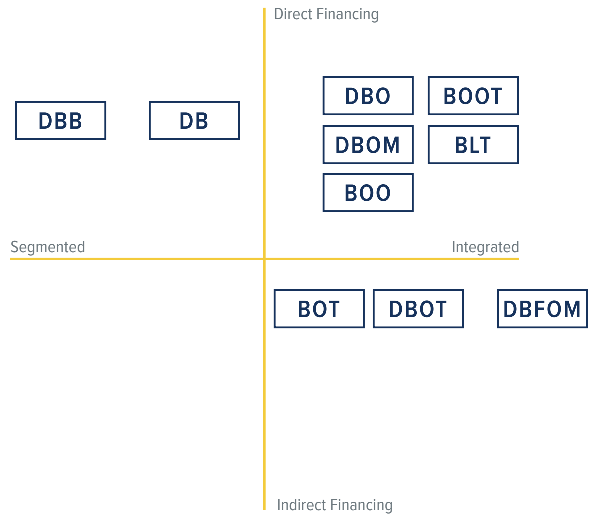
(or deliver) the project, may not have control over how carbon emissions are reduced over the course of the project's life cycle and/or any incentive to prioritize it.

Given that in the CVC the operation and use phases are responsible for a large portion of emissions, integrated project delivery models that include operation have greater potential for driving low-carbon behaviors. Similarly, projects where the owner has control over funding may increase the likelihood of carbon reductions by prioritizing it from the start of the project. Projects delivered via methods in the upper right quadrant (Figure 4) therefore have the greater theoretical capacity for carbon reduction over the asset life cycle.[26]

FIGURE 4: COMMON CVC PROJECT DELIVERY METHODS. THESE CAN BE CHARACTERIZED AS SEGMENTED TO INTEGRATED, AND DIRECT TO INDIRECT FINANCING.

PROJECT DELIVERY METHODS

- DBB — Design-Bid-Build (Traditional)
- DB — Design-Build
- DBO — Design-Build-Operate
- DBOT — Design-Build-Operate-Transfer
- DBOM — Design-Build-Operate-Maintain
- DBFOM — Design-Build-Finance-Operate-Maintain
- BOO — Build-Own-Operate
- BOT — Build-Operate-Transfer
- BOOT — Build-Own-Operate-Transfer
- BLT — Build-Lease-Transfer



Carbon pricing mechanisms

Through a literature review and observation of ongoing pricing schemes, the study identified six types of CPM:

- Internal carbon pricing.
- Emissions reduction credit schemes.
- Emissions trading systems.
- Hybrid schemes.
- Carbon taxes.
- Command and control.

Table 1 compares the strengths and weaknesses of the six CPMs. When compiling the table and considering how these CPMs could better integrate with the CVC, the following perspectives were considered:

- **Life-cycle stage:** Suitability of CPMs to be applied to the stages of the construction life cycle: product, construction, use, and end of life.
- **Asset class:** Suitability of CPMs to be applied to different asset classes, for example, buildings or infrastructure and subsectors of these.
- **Project scale:** Applicability based on project size.
- **Market:** Applicability based on market type, for example, low-, middle-, or high-income economy.
- **Project delivery method:** Project contractual approach which works most effectively with a CPM, such as DBB.

TABLE 1: THE STRENGTHS AND WEAKNESSES OF THE SIX CPMS.

Mechanism	How it works	Strengths and weaknesses
Internal carbon pricing	Voluntary mechanisms may be implemented by companies looking to manage risks from future climate policy, identify inefficiencies, and incentivize shifting from higher to lower emission technologies.[27] There are two main approaches: • Shadow pricing, which simulates the effect of an externally imposed tax on internal projects by adding a cost to projects. • Internal fees, which are imposed on specific business units based on their emission levels. Fees are centrally collected and reinvested, ideally in projects facilitating energy efficiency or carbon offsets.[28]	**Strengths** • Allows organizations to target specific internal business units with high emission levels. • Allows organizations to set targets to influence their supply chains, creating cascading changes throughout the system. • Drives innovation, which may lead a company to gain market share and grow the market for lower-carbon products and services.[29] • Acts as a risk management tool to understand how climate regulations will affect companies, helping them to prepare for an external future climate price.[30] • Familiarizes organizations with carbon pricing, helping them to prepare for a more rigorous and enforceable scheme. **Weaknesses** • Voluntariness may limit impact and narrow targeting may limit the effect across the whole business. • Lack of external regulation may result in low price setting (by an organization), limiting the overall impact of the policy. • May pose a risk to the competitiveness of an organization by raising costs that are passed on down the supply chain. • May be difficult to get financial executive buy-in. • May miss scope 3 (and sometimes even scope 2) emissions.
Emissions reduction credit (ERC) scheme	Under an ERC scheme[31] firms earn credits (or offsets) by reducing greenhouse gases below a predetermined level (for example, historical emissions level or emission intensity). Credits can then be traded with parties who need to comply with emissions targets regulations or who wish to offset emissions to become carbon neutral. In this way, ERC schemes can be integrated with ETS. Unlike ETS, there is no fixed limit on emissions, as credits are generated for each additional project.	**Strengths** • Credits can generate revenues, which may be reinvested in green initiatives. • Encourages efficiencies within high-carbon sectors. • Facilitates reporting of emissions reductions. • Provides a framework and rewards for offsetting, and encourages parties to consider other low-carbon initiatives. **Weaknesses** • Involves an administrative burden for verifying and vetting projects to ensure additionality.[32] • Potential for unintended incentives to keep business-as-usual emissions high to keep the baseline high and maximize the number of credits (and revenue) earned.[33] • Requires independent benchmarking. • Lack of fixed emissions limit may dampen actual emissions reductions.
Emissions trading system	ETS, or cap and trade systems, are market-oriented schemes that allow parties to buy and sell permits to emit greenhouse gases. ETS are quantity-based instruments in which an emissions upper limit is set (for example, x tons/year), and an associated number of tradable emission allowances (x permits to emit 1 ton) are either allocated or auctioned to polluters. Parties that do not use up all their permits can sell their surplus via international trading exchanges, thereby creating an incentive to reduce emissions.	**Strengths** • Theoretically creates an efficient market where emissions are reduced in the most cost-effective way. • Potential to generate revenues for governments (if emissions auctioned), which can be used to reduce negative impacts, for example, increased costs for certain sectors or impacts on competitiveness. • Attractive to business since there is potential for allocated allowances and related benefits (such as trading or banking allowances). • Potential for global-scale implementation and consequent reduction in the risk of carbon leakage (when businesses shift their production to countries with less stringent carbon regulations). • Certainty of emissions limit via a cap, subject to credible penalties and enforcement for non-compliance.[34]

Mechanism	How it works	Strengths and weaknesses
Emissions trading system *(continued)*		**Weaknesses** • Potential for carbon leakage, which may limit overall emissions reduction. • Potential for price volatility, which may affect business confidence. • Low price setting may limit impacts on emissions reduction. • Over-allocation of allowances and grandfathering may cause price crashes and rent-seeking behavior.[35] • Creation and oversight of market may be complex and costly.
Hybrid scheme	Hybrid schemes combine elements of quantity-based ETS instruments and price-based tax instruments.[36] For example, a hybrid option may involve having a cap and trade with a price floor and ceiling. Or the ETS may have an allowance reserve set, whereby when a permit price exceeds a certain ceiling, companies may buy a limited number of permits set aside (the reserve) for this purpose, at the ceiling price.	**Strengths** • Price volatility risks associated with market-based ETS are reduced by price floors and ceilings, which typically stabilize prices.[37] • Attractive to governments due to potential to raise revenue, assuming quotas are auctioned. • Creates flexibility to suit a variety of markets, for example, a price threshold may be used in lower-income economies to limit welfare impacts. **Weaknesses** • May be complicated and onerous to regulate, and may require more intervention in the permit market. • May be complex and costly to implement as a new emissions trading unit must be created and allocated.
Carbon tax	Taxation is a price-based instrument that sets a fixed price for carbon emissions.[38] Taxes can be implemented at different points along the supply chain; for instance, taxes can be levied on fossil fuel suppliers or final emitters.	**Strengths** • Simple to implement administratively, compared to market instruments. • Provides a clear price signal to the market. • Potential to capture the majority of emissions with just a few points of regulation. • Attractive to governments, as revenue generation may help compensate for negative impacts (such as raised prices and competitiveness). **Weaknesses** • Inaccurate price setting may limit effectiveness; significant analysis may be required to achieve the right price.[39] • Potential for carbon leakage. • May be politically unpopular and therefore difficult to implement, unless tax can be proven to be revenue neutral.[40]
Command and control	Although not a CPM, command and control regulations are compulsory policies that stipulate actions and penalties for non-compliance.[41] Such policies are generally applied across the board. Examples include emission limits, performance standards, and prohibiting the use of certain materials.	**Strengths** • Top-down implementation is simpler to enact and manage as no market or associated regulation needs to be formed. • Compulsoriness provides more certainty about a given target or outcome. **Weaknesses** • May be costly as regulations do not recognize that some businesses will face higher abatement costs and tend to have higher implementation costs than others. • Does not create an incentive to go beyond a certain level of reductions signaled by the target.

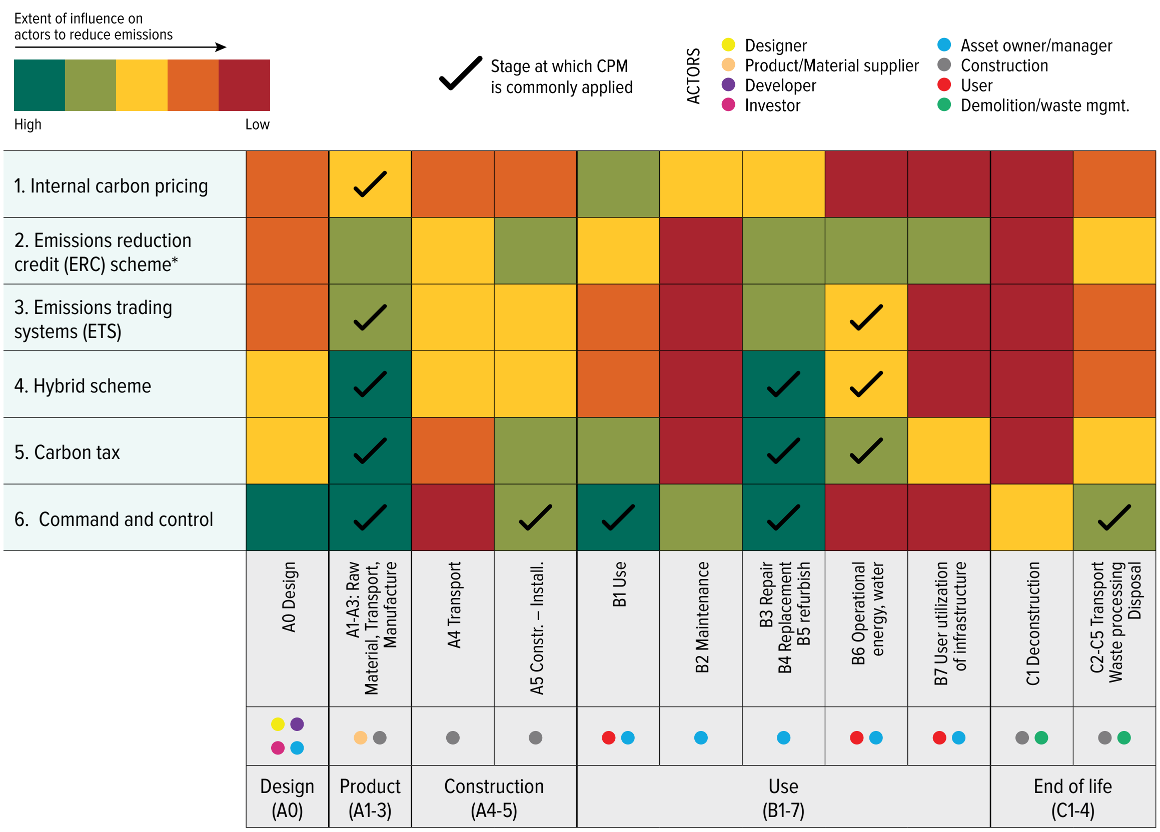
CPM influence heatmap

An influence heatmap was developed to indicate the scope and impact of CPMs across CVC actors and life-cycle stages. It was separately applied to each of the CPMs and is presented throughout the section on applying existing CPMs to the CVC.

Figure 5 applies the heatmap concept to all six CPMs. The image is based on common CPM application examples and shows the comparative influence (high to low) that the CPM applies to value chain actors to reduce carbon emissions.

Figure 5 only indicates potential. In practice, applying a CPM to a project and CVC context will show variation. The section on applying existing CPMs to the CVC discusses where it is best to target a CPM to maximize emissions reductions.

FIGURE 5: THE HEATMAP VISUALIZES WHERE CPMS ARE IMPLEMENTED IN THE CVC AND THE IMPACT ON THE ACTOR BEHAVIORS THEY CAN HAVE (THE COLORED CIRCLES INDICATE WHICH ACTORS ARE INFLUENCED OVER THE PROJECT LIFE CYCLE).



*An ERC scheme often requires the sustainability of the whole project to be evaluated, which is why a CPM is not placed on one particular stage.

Case Studies

To understand the potential for maximizing carbon reduction across the CVC, a scenario modeling exercise was undertaken. The modeling exercise demonstrates how applying CPMs at different stages in the CVC (product, construction, use) could influence the behavior of actors operating at those stages. The results indicate where a CPM should be targeted to maximize carbon reductions over the life of a project, which in turn helps identify the most suitable CPM, bearing in mind industry considerations and constraints (see above). For example, how CPMs may be modified or applied differently in high-, middle-, and lower-income economies, how actors in different life-cycle stages may be incentivized to reduce carbon, and how CPMs should be implemented in relation to other existing carbon reduction schemes and policies.

KEY MESSAGES

- Case studies of a road, a residential development, a commercial building, and a railway were modeled to understand how the application of CPMs at different stages in the CVC could influence the behavior of actors operating at those stages to reduce carbon emissions. The results of the analysis are examined in Chapter 4.
- Identifying the case study materials for this report proved challenging. No case study was immediately available that had applied carbon pricing to construction projects, perhaps reflecting the topic's newness within the industry. This provides useful context to several important lessons learned:
- **Data quality.** Project and life-cycle datasets were difficult to access. Data quality was poor and incomplete and different projects recorded data inconsistently. To facilitate robust carbon pricing across the CVC, such variations and data gaps must be resolved.
- **Guidance.** The case studies applied a standardized approach to determining greenhouse-gas emissions. However, this approach is not standardized in all markets and segments. There is also little guidance on how carbon pricing might be applied to CVC projects. Guidance on such aspects would help practitioners seeking to determine project-based carbon costs.
- **Capacity.** Case study development relied on engaging with project funders, architects, engineers, quantity surveyors, costing specialists, and suppliers, among many others. In most cases, much coaching was needed on carbon pricing and its application to the CVC. Skills and knowledge on carbon pricing remain limited among project stakeholders and will prove most challenging for smaller projects and operators who are less likely to have the relevant training capacity.

Methodology

Four existing projects were chosen and selected data from their project life cycles was modeled:

- N340 dual carriageway in Spain
- The Village residential development in South Africa
- One Mabledon Place, commercial building retrofit in the UK
- Awash-Weldiya/Hara Gebeya railway line in Ethiopia.

The projects differ in terms of asset class, project scale, and market. The analysis used project-specific information such as bill of quantities (detailed a statement of work setting out prices and quantities of materials required for the project) and complete life-cycle assessments to create datasets on which the scenario modeling was based. Where information was lacking or formats differed, assumptions were made and secondary research was carried out. In addition to consulting with Arup experts, external sources included the ICE carbon database, UK Environment Agency Carbon Calculation sheets, and the HM Treasury Green Book.

The research and assumptions reflect industry best practice and use expert guidance. However, it is important to note that with such variety of project types across the construction industry, the case studies cannot capture all life-cycle emission profiles and should therefore be considered indicative rather than representative of the industry.

LIFE-CYCLE EMISSIONS

The case studies examine the suitability of CPMs at different stages of the construction life cycle. The section on the CVC's structure sets out the generalized structure of these stages: product manufacture, construction, use/operation, and end of life. These terms can, however, shift in interpretation in practice. This is particularly the case when it comes to the activities associated with the operation and use of buildings and infrastructure. To help understand these terms, the Appendix includes a table that sets out what might be identified as operational and user carbon emissions in different buildings and infrastructure contexts.

Carbon price

A carbon price was applied to each ton of CO_2e emitted at each stage of the project life cycle. Low, medium, and high carbon price scenarios were created and applied to demonstrate how the application of CPMs at different stages in the CVC could influence the behavior of actors operating at those stages. The prices reflect the range of carbon prices currently implemented through CPMs globally. The low and medium carbon pricing regimes are intended to reflect the range at which most current carbon prices sit, while the high pricing regime represents the carbon price required in 2020 to stay consistent with achieving the temperature goal set out in the Paris Agreement.[42]

- **Low:** \$10/tCO_2e—based on the average EU ETS allowance price over the last year.
- **Medium:** \$25/tCO_2e—based on the IEA new policies scenario (2025) for the EU.
- **High:** \$53/tCO_2e—based on the IEA Sustainable Development scenario (2025) average of BRICS and advanced economies.

Case study profiles

The following profiles provide an overview of each case study and the analysis carried out on them.

N340 FOUR-LANE HIGHWAY, SPAIN

The N340 road is a four-lane highway in Alicante, Spain. It was developed by Acciona Infrastructure and obtained Environmental Product Declaration, which certifies the environmental footprint of the infrastructure during its entire useful life. The mode considered a 1-kilometer stretch; the life cycle considered is to 2050. The project followed a DBB delivery method.

Project characteristics

- **Stages considered in the analysis:**
  - Product (manufacturing of raw materials)
  - Construction
  - Operation (energy consumption of the lighting along the road)
  - Maintenance (repair the top layer)
  - Use (vehicular traffic using road).
- **Data:** The road owner, Acciona, provided a range of data, including key material quantities from a bill of quantities and life-cycle assessment inventory, and the cost per unit of these key materials. Additional research was carried out to inform the inputs and assumptions required for the analysis.
- **Carbon emission factor:** From Acciona's GABi modeling tool.
- **Electricity costs ($/kWh):** EC – Quarterly Report on European Electricity Markets, Spanish industrial retail electricity price—central consumption band assumed.
- **Discount factor for analysis of net present value:** 3.5 percent, from HM Treasury – The Green Book. Industry standard approach used in discounting future costs to present costs.
- **Carbon dioxide emissions during usage stage:** Based on Arup analysis from previous experience working with carriageways in the UK. This provides a proxy for road usage, based on similar road characteristics— standardized for 1 kilometer.

FIGURE 6: PHOTOGRAPH OF THE N340, SPAIN.

THE VILLAGE RESIDENTIAL DEVELOPMENT, SOUTH AFRICA

The Village is a low-rise residential development in Tshwane, South Africa, developed by Kale Developments. The total construction area is 16,000 m^2, comprising 288 one- and two-bedroom units. This study models data from 66 units. The life cycle considered in the model is to 2050. The project followed a Build-Operate-Transfer delivery method.

Project characteristics

- **Stages considered in the analysis:**
  - Manufacturing of raw materials (provided in bill of quantities)
  - Operation and use (annual energy consumption, both electricity and gas, of a user in a typical one-bedroom block).
- **Data:** The developer provided a bill of quantities listing the materials and associated costs across the project. Additional research was carried out to inform the inputs and assumptions required for the analysis (including density figures for raw materials, carbon factors, and average South African household consumption levels).
- **Carbon emission factors:** Taken from ICE V2 Emission Factors, University of Bath, based on kilogram of CO_2e per kilogram of material, converted using EACC database.
- **South African grid emission factor:** From UNFCCC and the Institute for Global Environmental Strategies, annual release figures.
- **Gas and electricity costs for use consumption ($/kWh):** Retail energy costs from South Africa's Department of Energy.
- **Discount factor for analysis of net present value:** 3.5 percent, from HM Treasury—The Green Book. Industry standard approach used in discounting future costs to present costs.
- **Carbon dioxide emissions during usage stage:** From Green Building Council schedules and DTS Energy Modelling Protocol Guide. Used to build load profiles based on average income.

FIGURE 7: PHOTOGRAPH OF THE VILLAGE RESIDENTIAL DEVELOPMENT, SOUTH AFRICA.

The Village (Clubview) is a property owned by IFC's client, International Housing Solutions (IHS). It has received final EDGE certification from the Green Building Council of South Africa.

AWASH-WELDIYA/HARA GEBEYA RAILWAY LINE, ETHIOPIA

The AKH railway project is building a railway line between the Ethiopian towns of Awash and Weldiya. The line will be 394 km long and will carry both passenger and freight traffic when complete in around a year's time. The life cycle considered in the model is to 2050. The project is using an Engineer-Procure-Construct delivery method.

Project characteristics

- **Stages considered in the analysis:**
    - Construction (heavy machinery such as excavators, backhoe loaders, trucks, and bowsers, and electricity required for powering accommodation, offices, and portacabins).
    - Operation and use (electricity needed for powering passenger and freight trains and diesel for freight transfer).
    - The product (raw materials) stage was not considered in this case study due to a lack of robust data.
- **Data:** The analysis drew on previous Arup estimates of emissions associated with building and operating the railway. Additional research was carried out to inform the inputs and assumptions required for the analysis.
- **Carbon emission factors:** Taken from US Environmental Protection Agency—Emission Factors, used in previous Arup studies of scope 1 and 2 emissions.
- **Ethiopian grid emission factor:** Taken from Ecometrica—Electricity-specific emission factors for grid electricity, used in previous Arup studies of scope 1 and 2 emissions.
- **Electricity costs ($/kWh):** Taken from US Commercial Service—Ethiopia: Power Sector Market Factsheet.
- **Discount factor for analysis of net present value:** 10 percent, from Asian Development Bank, World Bank Studies. This is an industry standard approach used in discounting future costs to present costs, relevant to a middle-income economy.
- **Power requirements during usage stage:** Used in previous Arup studies of scope 1 and 2 emissions.

FIGURE 8: RENDERING OF THE AWASH-WELDIYA RAILWAY, ETHIOPIA.

ONE MABLEDON PLACE, COMMERCIAL BUILDING RETROFIT, UK

The commercial building project is an existing building located in the west end of London, built in the 1960s and re-developed by Stanhope PLC under the project architect Bennetts Associates. It covers 13,032 m^2 and consists of a 10-story tower, a four-story annex building, and a conference hall. This case study focuses on planned refurbishment work, rather than new-build construction. The life cycle considered in the model is from 2013 to 2063. The project followed a Design-Construct delivery method.

Project characteristics

- Stages considered in the analysis:
    - Product and material manufacture
    - On-site construction activities
    - In use, including maintenance
    - End of life.
- A carbon footprint for the refurbishment work, together with expected operational emissions and analysis of how these compare to the emissions from the original building, is also provided.

FIGURE 9: PHOTOGRAPH OF ONE MABLEDON PLACE, UK.

Applying Existing Mechanisms to the Construction Value Chain

This section assesses how existing CPMs can be adapted to better capture emissions along the CVC. Section narratives focus on the aspects deemed most relevant to the specific CPM and the CVC, and therefore vary in content and discussion. Throughout, evidence from the case study modeling work is used to support the findings.

Internal carbon price

Internal CPMs are increasingly used in business and industry to manage carbon risk exposure and plan future investment strategy. Between 2014 and 2017, the number of global companies disclosing to CDP that they embed an internal carbon price into their business strategies grew from 150 to almost 600.[43] In the CVC, companies including Acciona, Cemex, LafargeHolcim, and Siemens are considering or already implementing internal CPMs.[44] While early indications suggest that some of these mechanisms have been successful, the companies also report ongoing challenges with internal CPMs, including risks to competitiveness, misalignment between policies and approaches across different geographies and jurisdictions, and a lack of standardized and comparable frameworks to aid scenario analysis.[45]

Internal CPMs enable companies to quantify climate risks, helping them to create metrics that financial decision-makers can use to support their investment decisions and future strategies. As a large portion of a company's emissions are likely to be associated with its supply chain, applying an internal CPM can also help companies engage with and influence these external parties. The Financial Stability Board's Task Force on Climate-related Financial Disclosures is helping to advance this agenda, providing leadership and guidance for those concerned about their climate risks.[46]

However, because internal carbon pricing is voluntary, it lacks the global coverage and associated impacts that a more compulsory mechanism like a carbon tax has on reducing emissions. Nonetheless, as companies and their supply chains become more familiar with internal carbon pricing, and reporting becomes the norm, the potential for broadening the scope of internal CPM increases.

As shown in Figure 11, applying an internal CPM to the product (materials) phase of the CVC would result in increased costs of 2 percent to 6 percent for the N340 road and 3 percent to 15 percent for The Village residential development (as a percentage of total raw materials costs and measured at the point of construction).[47]

KEY MESSAGES

- Global carbon prices need to be higher (between $25 to $53/t$CO_2$e) to trigger changes in behavior along the CVC. At a low carbon price ($10/t$CO_2$e), additional costs can be absorbed by the polluter or passed on in a way that is affordable to downstream CVC actors and their customers.
- CPMs must focus more on the early CVC life-cycle stages such as design and funding. At present, CPMs focus on materials manufacture and construction, and operation and use. To be more effective, CPMs must also target the stages and actors associated with early stage project-making, including funders, developers, and designers, where decisions that influence carbon emissions are often locked in.
- However, since the vast majority of emissions are generated during the operation and use phases of the asset (at least in the case studies), these stages must also be addressed. As decarbonization increases, we will see a comparative shift in emissions from these later stages to the earlier stages (such as materials manufacture). To ensure CPMs are effective and sustainable over the long term, they need to incentivize actors from designers downwards to improve efficiency at all stages of the CVC.
- Including constructed assets in CPMs could help incentivize project-making actors to address project emissions or face pricing penalties. For example, by including new building projects in an ETS, the scope of influence could extend from some hundred or so assets in a single country (for example, power stations) to hundreds of thousands, or even millions of assets, with clear advantages for carbon reduction.
- Market-based instruments like ETS are effective for large, industrial emitters in higher- and middle-income economies, where high administrative costs can be accommodated and rules enforced. Conversely, a carbon tax can be applied by any administration, making it viable in high- as well as lower-income economies, notwithstanding the political challenges of implementing taxes. A well-designed hybrid mechanism can combine the benefits of market mechanisms like ETS with other approaches like price floors and ceilings, making them more flexible and effective in capturing CVC emissions.
- Integrated project delivery methods can effectively internalize life-cycle considerations such as low-carbon ambitions along the CVC. This is particularly powerful when the CVC retains responsibility for the asset's operation and use. This may help to incentivize project actors to look at the full life cycle in a planned, holistic, and balanced way.
- The design and application of CPMs in the CVC has the potential to create unintended incentives and unintended outcomes. For basic-needs infrastructure, the impacts on affordability and citizen welfare need to be carefully considered. A poorly designed CPM could increase housing costs and lead to higher life-cycle carbon emissions (for example, encouraging single glazing over double glazing alternatives), with particular impacts in lower-income social housing brackets.

FIGURE 10: **ASPHALT AND CEMENT-BASED PRODUCTS WERE FOUND TO HAVE THE HIGHEST CARBON COST OF MATERIALS, AS A PERCENTAGE OF TOTAL MATERIAL COST FOR THE ROAD (LEFT) AND RESIDENTIAL DEVELOPMENT (RIGHT).**

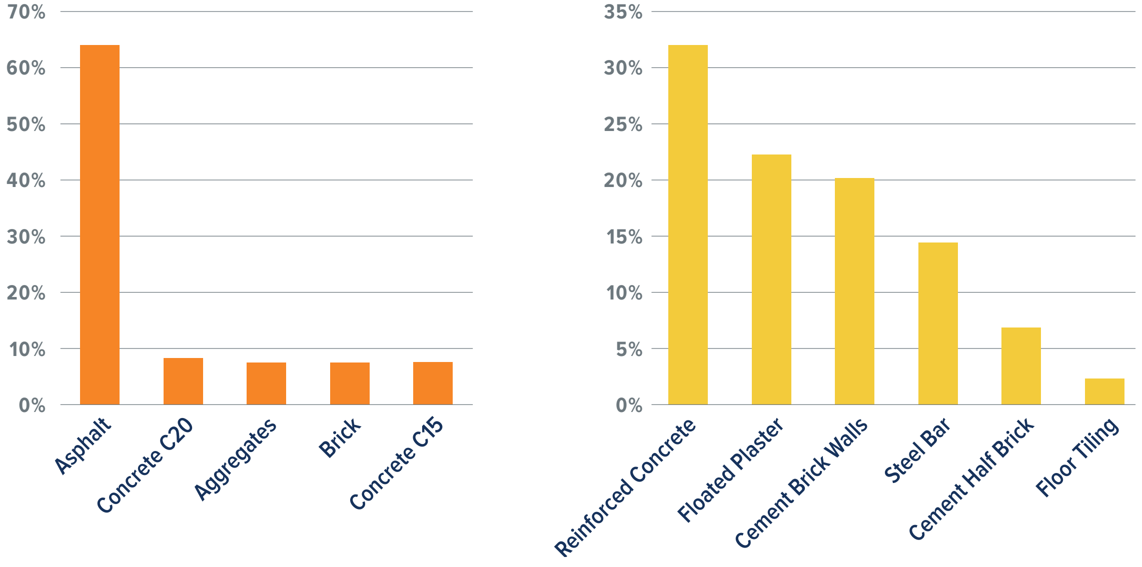
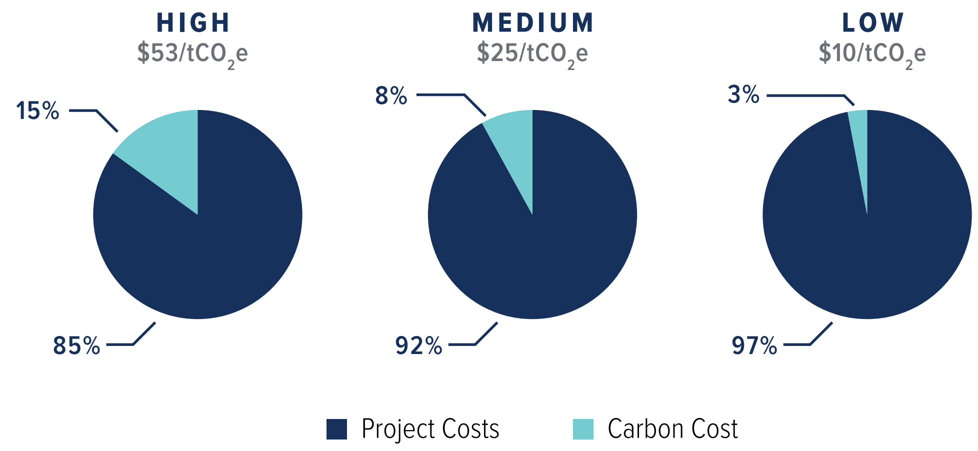


FIGURE 11: CARBON COSTS AS A PERCENTAGE OF TOTAL RAW MATERIAL COSTS FOR THE VILLAGE RESIDENTIAL DEVELOPMENT. IF A CPM WERE APPLIED AT THE MATERIALS STAGE OF THE CVC, ADDITIONAL CARBON COSTS WOULD BE SUFFICIENT TO CATALYZE A SHIFT IN BEHAVIOR ON THIS DEVELOPMENT.



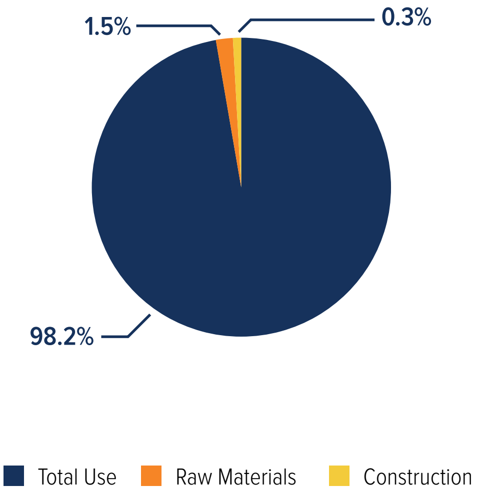
These percentages are significant enough in scale to catalyze a shift in behavior by the actors affected, including:

- The client as they set out project objectives
- The design team as they respond
- The contractor as they procure and build.

However, this change in behavior would most likely occur if the client (that is, the organization commissioning and potentially financing the project) applied the CPM. This is because they would be able to pass the burden of the carbon cost on and hence focus the project implementers on its reduction. By comparison, a mechanism applied unilaterally by the project designer (and to some extent the contractor) might conflict with client objectives.

More significantly, in both cases the emissions from use (for example, vehicle emissions and building inhabitants' use of gas or electricity) vastly outweigh those from other CVC phases (as shown in Figure 12 for the road and Figure 13 for the residential development). This means that if an internal CPM addressed use and operational emissions by applying a cost to energy or fuel use, it would incentivize developers to develop a project that had lower operational emissions. However, as further discussed in the section on carbon tax, decarbonization of the electricity grid will reduce operational emissions, making the raw material phase a comparatively more significant contributor to CVC emissions.

FIGURE 12: IN THE CASE OF THE ROAD, EMISSIONS FOR THE USE STAGE VASTLY OUTWEIGH THOSE FROM THE OTHER CVC STAGES. THIS COMPRISES EMISSIONS FROM VEHICLE USAGE AND A VERY SMALL AMOUNT FROM LIGHTING THE ROAD.

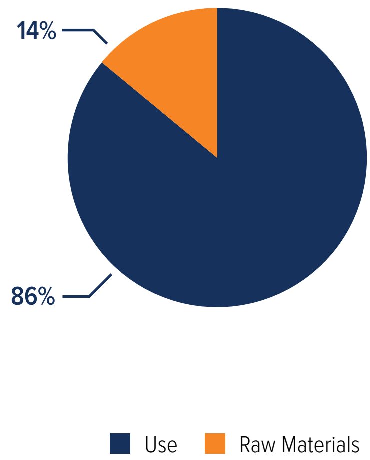


On the other hand, and as shown in the heat-map in Figure 14, although internal CPMs tend to be applied to the product and use stages of the CVC, their voluntary nature means that users may choose not to burden themselves with additional costs. However, this overlooks the benefit of applying an internal CPM, which is to provide organizations (and those charged with strategic and financial decision-making) with insights on operational and supply chain carbon risk exposure, capacity building, and leadership and reputational benefit among peers, and thus encourage low-carbon decisions.

Another constraint is that project designers do not usually apply internal CPMs, as this would make them liable for their design projects, along with facing a number of potential down-side risks associated with such an approach, including:

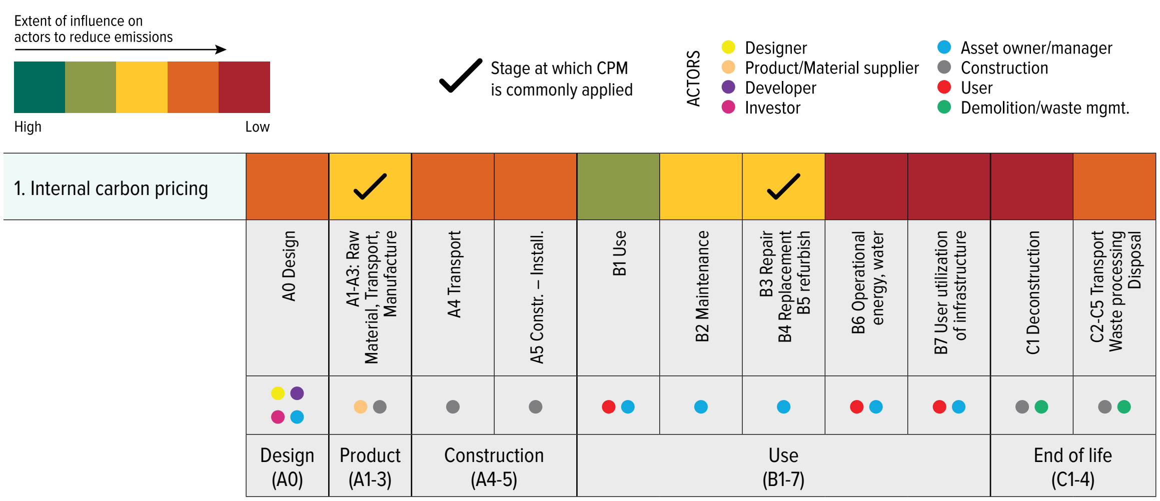
- Creating cost where none existed previously, thus potentially impacting competitiveness.
- Making certain project types and services they have incompatible with the CPM objectives.
- Bringing the design service provided into conflict with the objectives of the client or other project actors.

FIGURE 13: EMISSIONS FOR THE USE STAGE VASTLY OUTWEIGH THOSE FROM THE OTHER CVC STAGES IN THE CASE OF THE VILLAGE DEVELOPMENT. THIS COMPRISES EMISSIONS FROM ELECTRICITY AND GAS USAGE. CONSTRUCTION DATA WAS NOT AVAILABLE FOR THIS CASE STUDY.



Voluntary schemes are likely to be most effective for companies that own and operate buildings and construction assets (preferably via integrated procurement routes), and that have a long-term pipeline of similar projects.

FIGURE 14: THE VOLUNTARY NATURE OF AN INTERNAL CPM MAY RESTRICT ITS EFFECTIVENESS IN LOWERING EMISSIONS ACROSS THE CVC.



Internal CPMs may be more applicable in higher-income markets, where the relative higher cost of producing carbon-intensive products can be recouped from the market. The Village case study shows that where project costs (for construction and raw materials) are lower, an internal carbon price set at the medium range of $25/tCO_2e$ would add an additional 10 percent to product costs, making the project potentially unfeasible.

Summary

An internal CPM could be used by high-carbon material suppliers to incentivize product substitution (for example, high fly-ash-content concrete) that offers a low-carbon alternative and improved performance.[48,49]

However, the mechanism will not influence behavior unless a reward metric is introduced to incentivize designers to incorporate elements that reduce carbon in their designs from the start of a project. Possible incentives include lump-sum rebates, exemptions, or funding for low-carbon research and development. Further economic analysis would be needed to determine the most appropriate form of compensation and calculate the relevant functioning in a given industry or company. Ideally, compensation would be temporary, with clear phase-out plans as firms adjust and competitiveness concerns subside.

An integrated delivery model (such as DBFOM) might help raise awareness of carbon when making design choices that cascade down the supply chain. However, designers and client organizations are unlikely to add significant financial and administrative burdens to their projects without being compensated or heavily incentivized. Moreover, they may not be capable of applying internal CPMs to their operation and use phases—where there is the greatest potential to reduce carbon emissions in the CVC—unless they operate under an integrated delivery model that allows them to influence operation and use activities.

Establishing and managing internal CPMs can be costly and difficult due to administrative and verification requirements, potentially making it more challenging in lower-income economies. Similarly, where higher costs are incurred compared to competitors as a result of internal mechanisms, middle- and higher-income economies may more easily absorb or recoup such costs from the market. Nonetheless, international organizations may use their resources to support parties in their supply chains (especially in lower-income geographies) to improve efficiencies while avoiding the possible negative impacts of introducing an internal carbon price. Collaboration is critical to establishing and operating an internal CPM as it ensures all parties understand their role and have the knowledge and resources to make the necessary changes.

The global influence on internal CPMs in the CVC is still at the scaling phase. Although they are secondary to the large-scale and more compulsory mechanisms that exist, about 600 companies worldwide have implemented internal CPMs, and interest is growing, with as many as 1,400 companies reporting that they are planning to implement a scheme.[50] Other challenges include a lack of clarity on how to measure emissions, uncertainty regarding how to apply an internal CPM consistently across investment and lending portfolios, uncertainty about how to measure what an appropriate carbon price is, and the potential threat to competitiveness from a lack of a level playing field.

In the CVC, organizations' unwillingness to internalize costs and project emissions remains an obstacle to widespread uptake of CPMs. However, as environmental regulations become stricter, the quality of information on carbon increases, and more organizations report the benefits of using internal CPMs, companies in the CVC are likely to follow suit and work together to overcome the remaining barriers and increase the effectiveness of internal CPMs throughout supply chains.

Emission reduction credit scheme

Operating facilities earn emissions reduction credits (ERCs) when they shut down or voluntarily reduce their emissions. This may be to offset increases in emissions in one area (for example, to compensate for new construction or expansion of existing facilities). ERC schemes are suited to industries where there is a limit to the reduction of emissions that can be achieved, such as high-carbon industries, or in countries attempting to gradually reduce emissions in line with a date (such as South Africa, which plans to peak emissions by 2025[51]). ERCs require robust verification processes. Although this results in an additional cost, in theory there is no obstacle to ERC schemes being applied in lower- to higher-income economies.

Analysis of the case studies indicates that applying a CPM to materials could result in additional carbon costs sufficient to incentivize a switch to lower-impact materials and processes (see Figure 15). In such a scenario, an ERC scheme could be established to trade ERCs. This would allow the carbon profile of the entire residential development or portfolio of developments to be assessed, thus allowing an asset owner or developer to trade credits across their whole scheme or portfolio of schemes, as shown in Figure 16. In this way, as the heatmap indicates, ERC schemes have the potential to influence multiple CVC stages. However, as there is no obligation to earn ERCs, participants must first be incentivized to join such a scheme.[52]

A regulated market is needed to create and trade ERCs. In the meantime, existing programs such as the Clean Development Mechanism can be used. In the CVC, ERC schemes might be most appropriate at the sector level and in relation to the most carbon-intensive materials or large-scale asset classes (for example, building portfolios or infrastructure works programs). As such, the ERC approach has the potential to accommodate varying asset types and levels of economic income. For example, an ERC scheme could be applied to the retrofitting of existing buildings to improve energy efficiency, something that high-income markets with large existing building stocks will benefit from. By contrast, in lower- to middle-income markets, the focus could be on awarding credits to different industries (such as steel and concrete) or to discrete target development sectors (such as water utilities or social housing programs).

FIGURE 15: THE ROAD CASE STUDY SHOWS THAT EVEN UNDER THE LOW-PRICE SCENARIO, APPLYING A CPM TO THE RAW MATERIALS STAGE WOULD BE SUFFICIENT TO INCENTIVIZE BEHAVIOR CHANGE IN RELATION TO THE DEVELOPMENT.

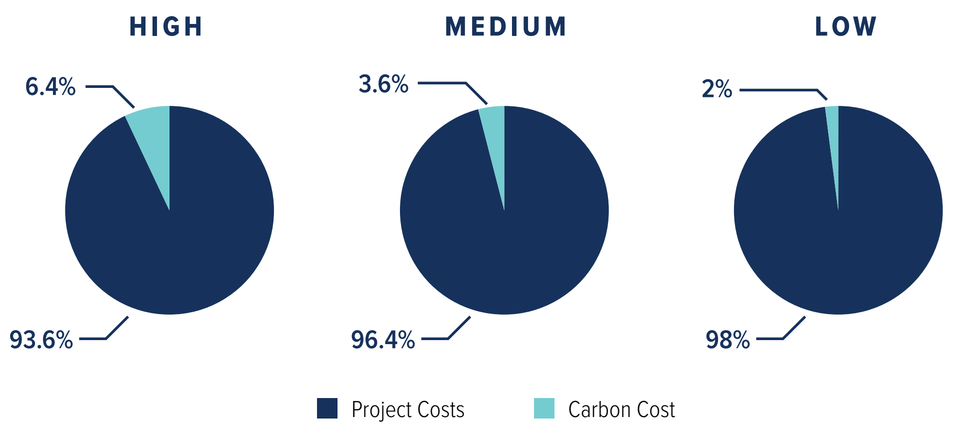
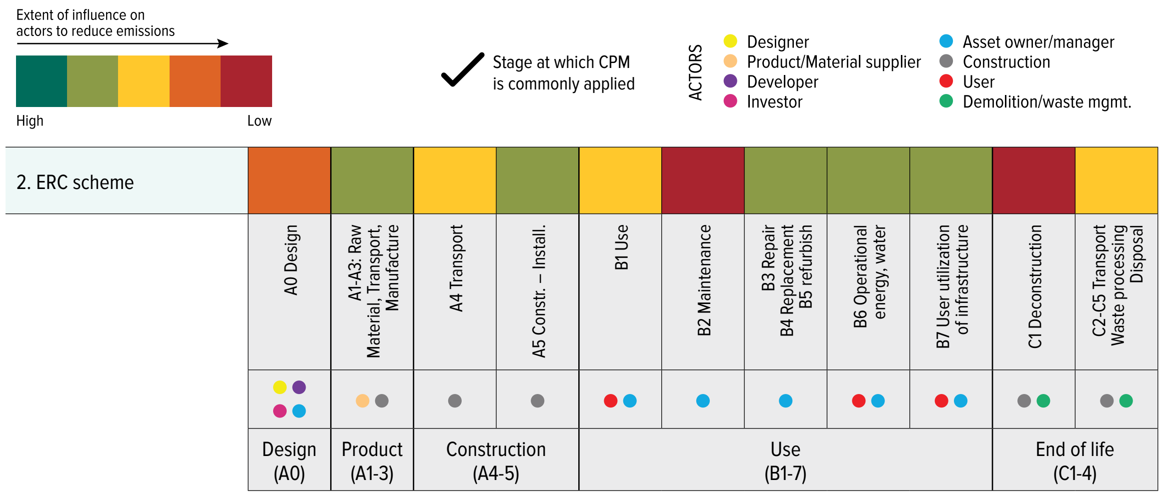


FIGURE 16: AN ERC SCHEME OFTEN REQUIRES THE SUSTAINABILITY OF THE WHOLE PROJECT TO BE EVALUATED; THEREFORE, A CPM IS NOT PLACED IN ONE PARTICULAR STAGE BUT ACROSS ITS ENTIRETY.



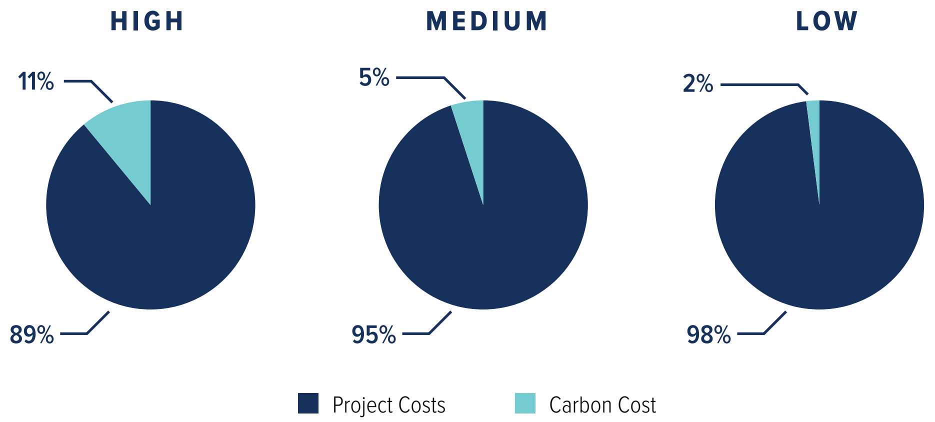
In the CVC, a project like a commercial building might choose to participate in an ERC scheme, allowing both the materials and construction stages to be targeted. The lack of a fixed number of credits under ERC means that new credits can be created for each additional project. This approach would not penalize retrofitting of commercial developments. For example, if a blanket carbon price was applied to all building developments without taking account of improved efficiencies from retrofits, the market might be discouraged from making retrofit improvements.

Using an ERC scheme to influence user emissions in the CVC does, however, present several implementation difficulties related to usage type. In the case of a road, for example, an operator would not impose an emissions target on users since neither party can reduce emissions in this area. In such cases, alternative approaches, such as toll roads or low-emissions zones, that are simpler to implement and more effective at changing behaviors along the value chain would be needed.

Summary

In the CVC, an ERC scheme could allow carbon-intensive industries and large assets to manage emissions cost-effectively. An ERC scheme could also be applied to influence the emissions of larger-scale users such as commercial buildings. It could be adapted and tailored to a project and geography, allowing for greater flexibility and the inclusion of a wider range of assets, and to avoid discouraging industry development. This could be applied to projects and sectors in different economies. However, while building projects could participate in an ERC scheme, the administrative burden of having to assess every project and award credits accordingly would be notable.

FIGURE 17: ACROSS ALL THREE CARBON PRICE SCENARIOS (HIGH, MEDIUM, LOW, LEFT TO RIGHT), CARBON COSTS CONTRIBUTE BETWEEN 2.2 PERCENT AND 10.6 PERCENT OF TOTAL PROJECT COSTS FOR THE USE STAGE OF THE AKH RAILWAY. AT ANY PRICE LEVEL, A CPM AT THIS STAGE COULD INFLUENCE BEHAVIOR.



Emissions trading systems

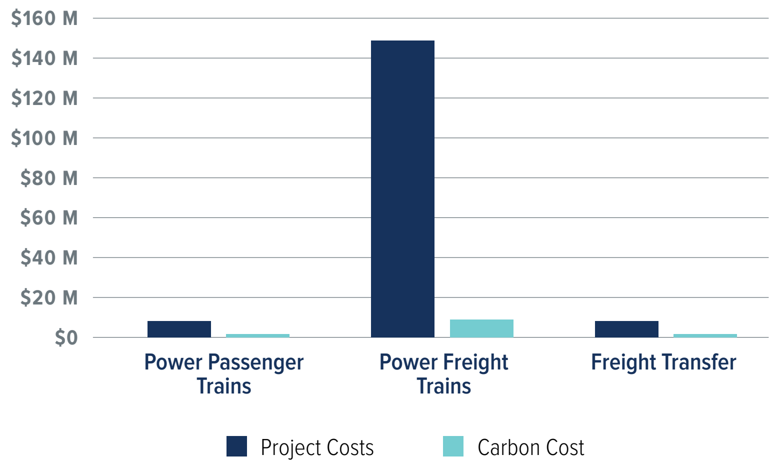
ETS are perhaps the best-known CPM. Emissions trading is a market-based instrument in which an emissions limit is set and tradable emission allowances up to that limit are allocated or auctioned. By defining an emissions cap, emissions trading provides a degree of certainty not present in other approaches. This also increases the potential for alignment with NDCs.

Designing and managing an ETS requires iterative administrative effort to, for example, decide the scope, set the cap, distribute allowances, ensure compliance, and engage stakeholders. While an ETS may be established anywhere with sufficient parties to trade allowances, in practice, it will not be truly credible or effective unless rigorous planning is carried out and regulated management processes (such as reporting and compliance) are in place. This may make ETS better suited to markets where relevant regulatory structures are or could be established, and high administrative costs can be absorbed by the market. Extensive planning, ongoing verification, and a binding and enforced system of penalties are essential to maintain a viable market in which participants can have confidence.

The case studies demonstrate that an ETS would be effective at the materials stage of the CVC, particularly for high-carbon products, or in some cases on fuel associated with operations and use (Figure 17). An ETS is relevant to both the infrastructure and building sectors.

In the AKH railway case study in Ethiopia, where use stage emissions are high, the producer of the fuel used in the operation and use stages could participate in an ETS. However, the scale of the Ethiopian market may not be sufficient to support such a scheme. The railway company would need to avoid rail tickets increasing to unaffordable levels for consumers due to the additional costs associated with the ETS.

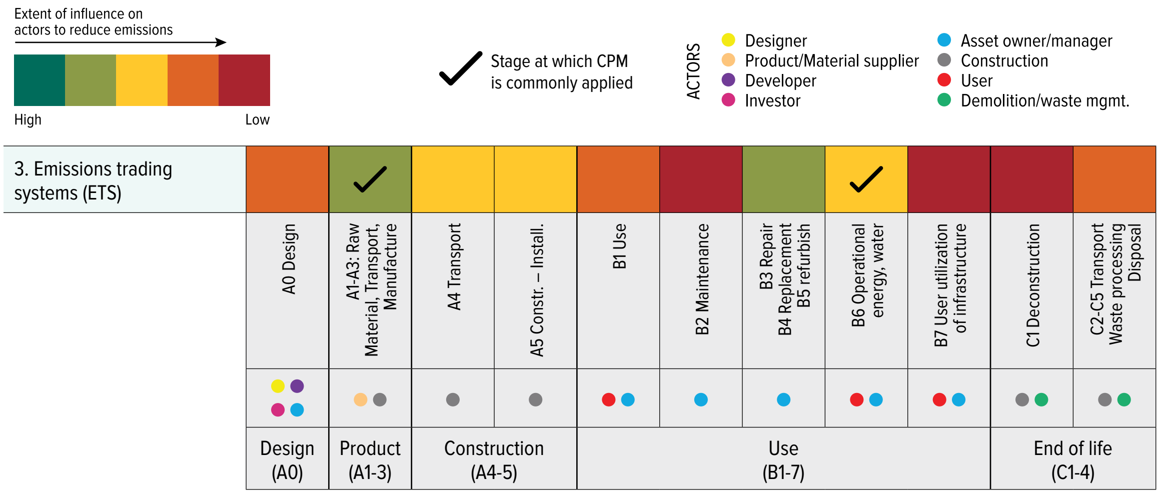
FIGURE 18: PROJECT AND CARBON COSTS WERE FOUND TO BE SIGNIFICANTLY HIGHER FOR FREIGHT TRAINS THAN FOR PASSENGER TRAINS IN THE AKH CASE STUDY (FREIGHT TRANSFER COSTS RELATED TO DEPOTS USED FOR LOADING AND UNLOADING).



A significant proportion of the cost incurred in the use stage of the AKH case study was associated with procuring electricity for powering freight trains. This was driven by high daily power demand of over 1GWh/day. These costs relate to a lifespan to 2050, and have been discounted at 10 percent. The results demonstrate that, at $8.4 million, the total electricity used to power freight trains could be a worthwhile target for a CPM. Power freight train activities contribute about 91 percent of all carbon costs incurred during the use stage, further supporting the case for an ETS in this area.

Figure 19 shows that emissions trading is commonly applied to the product (such as

FIGURE 19: EMISSIONS TRADING HAS THE POTENTIAL TO STRONGLY INFLUENCE BEHAVIOR AT THE MATERIALS AND OPERATION/USE STAGES.



materials production) and use (such as power generation) stages of the CVC. However, there is also potential to apply it at the buildings and asset level. This may encourage developers to consider retrofitting existing buildings instead of building new ones. Retrofitting may be especially relevant in economies with considerable existing buildings. For example, in the commercial building case study, operational emissions made up 89 percent of whole-life emissions and retrofit provided a low-carbon solution as compared to a new building. Figure 20 presents the case for retrofitting buildings, which has a carbon payback period of about five years, compared with 14 years for a rebuild project.

In economies expecting significant growth with corresponding new construction demand, a new building or asset could be included in an ETS built environment scheme. Assuming an integrated delivery model is applied, this would accelerate the cascading of requirements to reduce carbon throughout the project life-cycle stages and associated actors, encouraging everyone from designers to contractors to choose low-carbon materials and employ efficient practices.

Applying an ETS to material suppliers would need to be carefully considered against any downside risks such as carbon leakage and loss of competitiveness. The most carbon-intensive sectors (such as steel, cement, and aluminum) could be significantly affected by carbon costs (as shown in Figure 21), potentially driving them to shift their operations to jurisdictions where carbon pricing is not applied. As more jurisdictions apply ETS and taxes, this issue will be minimized. In the meantime, a form of border tax adjustment could be used, although it would need to be assessed against World Trade Organization regulations to ensure compatibility.[53]

Summary

In the CVC, an ETS may be applied at the product stage and, in some cases, on fuel used in operations and use. There is potential for construction projects to participate in an ETS, which could increase emissions-related prices for all parties involved in a project and may encourage designers and client organizations to build in carbon reduction early in the development process to avoid additional costs. This

FIGURE 20: **THE COMMERCIAL BUILDING CASE STUDY ILLUSTRATES THE POTENTIAL OF RETROFITTING OVER NEW BUILD WITH CARBON SAVINGS UP TO 4,000 TONS OF CO_2e OVER THE ASSET'S LIFE.**

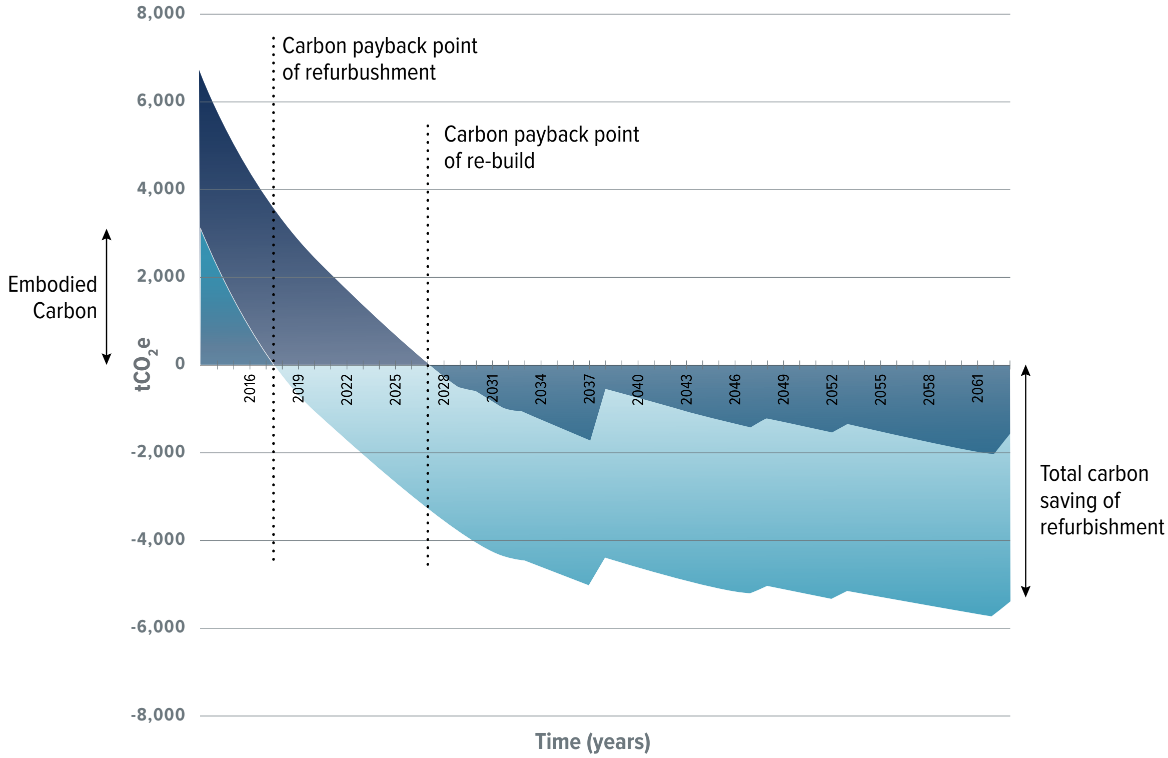
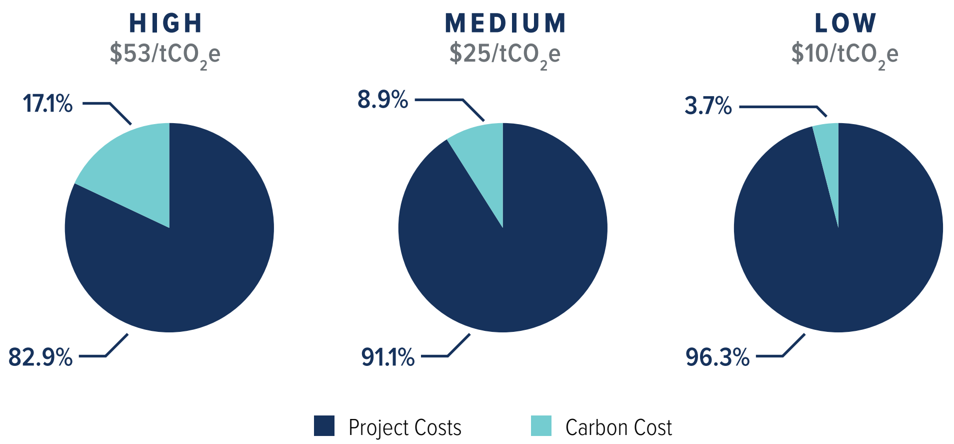


FIGURE 21: **APPLIED TO THE CONSTRUCTION STAGE OF THE AKH RAILWAY, CARBON COSTS WOULD CONTRIBUTE BETWEEN 3.7 PERCENT AND 17.1 PERCENT OF TOTAL PROJECT COSTS. AT ANY OF THESE PRICE POINTS, ACTORS WOULD BE INCENTIVIZED TO ALTER THEIR BEHAVIOR, SUGGESTING AN ETS AT THIS STAGE COULD BE EFFECTIVE IN LOWERING EMISSIONS.**



will require oversight by an actor responsible for trading credits and recognition of energy efficiency measures. As buildings have high operational emissions, under certain circumstances this may encourage developers to consider retrofitting over new-build construction, further reducing emissions. In emerging markets emissions trading has the potential to significantly impact future emissions, locking in low-carbon operation and catalyzing and mainstreaming low-carbon materials manufacture and construction methods.

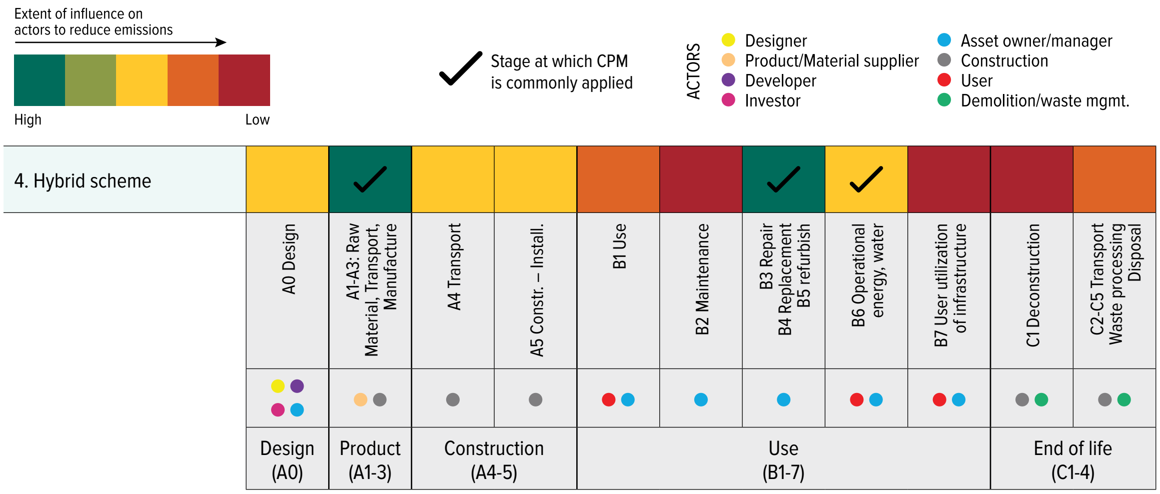
In some cases, influencing use emissions may be challenging as these are often generated at a smaller scale (for example, by individual cars or home inhabitants) that may be difficult to capture within a trading scheme. The impact of price increases on certain users (such as low-income, high energy users) and the potential for unintended consequences (for example, rail ticket price rises resulting in a shift to individual car use) must be considered.

Further research is needed to understand the possible impacts of including buildings and infrastructure in an ETS. Calculating equitable price caps, allocations, and compensation for high-carbon industries and households is complex. Ensuring that the structure has a meaningful impact on emissions (now and in the future), while avoiding negative impacts on competitiveness and welfare, requires detailed assessment, political negotiation, and close engagement with sectors likely to be affected. Some of these issues are addressed in more detail in the section on applying CPMs to the CVC.

Hybrid scheme

Hybrid schemes combine elements of quantity-based emissions trading instruments and price-based tax instruments. A hybrid model applied to the CVC has the potential to provide flexibility to accommodate varying asset classes and scales, allowing it to be applied in lower-, middle-, and higher-income markets. A hybrid solution may be applied at various points along the CVC and thus take advantage of the positive impact from the characteristics of more than one CPM. For example, in the UK the EU-ETS is applied in combination with a carbon price floor. This flexibility is illustrated in the multiple application points shown in Figure 22.

FIGURE 22: **HYBRID SCHEMES HAVE THE POTENTIAL TO INFLUENCE ACTORS AT MULTIPLE POINTS ALONG THE CVC.**



To be viable, effective, and equitable, the carbon price must be set at a level that reflects specific market characteristics. In some lower- and middle-income countries, a low initial carbon price and threshold may be appropriate to establish a market that can be enhanced over time. Hybrid solutions are flexible to this approach. A phased approach to CPM operation would allow industry to adopt new technologies and encourage behavioral change gradually, without creating sudden burdens on certain groups.

Analysis of The Village case study in South Africa found that even under the low carbon price scenario ($10/t$CO_2$e), an additional 7 percent (see Table 2) would be added to annual consumer bills. This could prove unaffordable for many households. To limit the increase, a threshold could be set to allow for tax-free carbon emissions below a certain level, gradually increasing over time. If a mechanism was applied to the materials stage, under the low pricing scenario, 3 percent would be added to project costs. This is still a significant increase with the potential to shift behavior by, for example, incentivizing lower carbon material choices (Figure 11).

To counteract potential negative impacts on user welfare and generate socioeconomic improvements, a green dividend may also be applied, allowing the revenue generated by the CPM to be disbursed back to consumers in the form of vouchers or credits for green products (for example, domestic energy efficiency measures, education, or health care).

A hybrid solution may also catalyze fuel switching, as in the case of the UK carbon price floor, which successfully drove the shift from coal to gas. Hybrid options often include exemptions for certain high-carbon industries, but these may be phased out over time.

Summary

A hybrid scheme has the potential to combine the benefits of strong established market mechanisms like an ETS with other approaches like price floors and ceilings, which more closely reflect external market conditions. This approach also captures emissions that under an ETS on its own would remain unpriced (such as smaller-scale user emissions from buildings or cars). However, by combining CPMs, hybrids also create additional complexity and the alignment between these systems needs to

be assessed. A discussion on double counting when combining two CPMs is detailed in the section on applying existing CPMs to the CVC.

The case studies illustrate that applying a threshold would allow participants (particularly those only starting to implement carbon pricing) to alter their practices gradually while limiting negative impacts. A hybrid mechanism could be applied to multiple actors across the CVC, allowing for application across a broad range of project delivery methods, asset classes, scales, and markets. Hybrid schemes can also be adjusted to apply in different markets, although high administrative burdens may present challenges in some lower-income economies.

A hybrid CPM can be applied at various points along the CVC, as shown in Figure 22.

Thresholds may be used to help prepare market participants for stricter regulations and ease the immediate burden on lower-income projects and economies. A hybrid with a permit price and allowance reserve could be applied across multiple CVC stages and actors, negating the need for a single responsible actor. Integrated project delivery methods such as DBFOM; Build-Operate-Transfer; and Design-Build-Operate-Transfer could all work well with hybrid schemes.

Given the wide variety of project types, sizes, and project delivery methods in construction, a hybrid CPM may be the most flexible and effective way to capture emissions from across the CVC.

TABLE 2: **COMPARISON OF THE LOW CARBON PRICE MODELED FOR THE VILLAGE CASE STUDY ($10/TCO$_2$E) WITH SOUTH AFRICA'S PROPOSED THRESHOLD RATE OF $9, WHICH, AFTER THE THRESHOLD IS APPLIED, WILL RESULT IN AN ACTUAL RATE OF BETWEEN $0.45 AND $3.58 PER TON OF CO$_2$E.**

Stage	Low carbon price ($10/tCO$_2$e)	South African carbon tax price ($3.58)	South African carbon tax price ($0.45)
Product (materials)	3%	1.2%	0.14%
Use	7%	3%	0.3%

Carbon tax

A carbon tax is a price-based instrument that sets a fixed price for carbon emissions. In the CVC, a carbon tax may be most appropriate where there is a strict emissions target in place or where the potential for creating an emissions market is limited. This could be a lower- or middle-income economy or a smaller-scale asset or project. A tax may also be better suited to certain sectors such as fuel, where the potential for decarbonization increases effectiveness. By comparison, there may be greater challenges associated with decarbonization for a sector like cement, which may require further development and expansion of technologies like carbon capture and storage or clinker alternatives. A tax may also be set low and increased over time to ease the initial burden of compliance and limit impacts on certain sectors and groups.

South Africa is introducing a carbon tax, which is set to take effect in January 2020. The tax rate is set at R120 per ton of CO$_2$e (about $9). To give businesses time to transition, a basic percentage-based threshold of 60 percent will apply, below which tax is not payable.

A phased carbon tax on fuel might also be viable and would affect all CVC stages. It would also avoid discouraging the development of transport projects and give developers time to prepare for the future higher tax rate.

The case studies illustrate that applying a tax to the materials and construction stages could have immediate impacts for constrained industries. For example, to avoid increased materials costs in the short term, a contractor might seek to substitute carbon-intensive materials. In the longer term, this may be compounded as the power sector decarbonizes and building systems electrify. Through this, a larger share

FIGURE 23: UNDER A DECARBONIZED SCENARIO, EMISSIONS FROM RAW MATERIALS WILL BE COMPARATIVELY HIGHER THAN FOR USE.

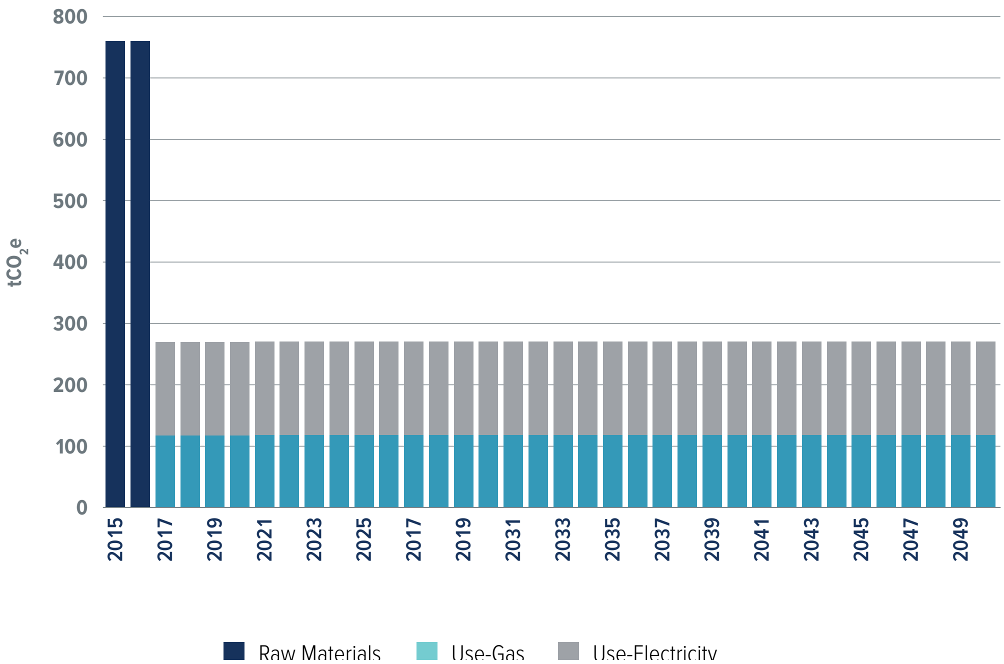
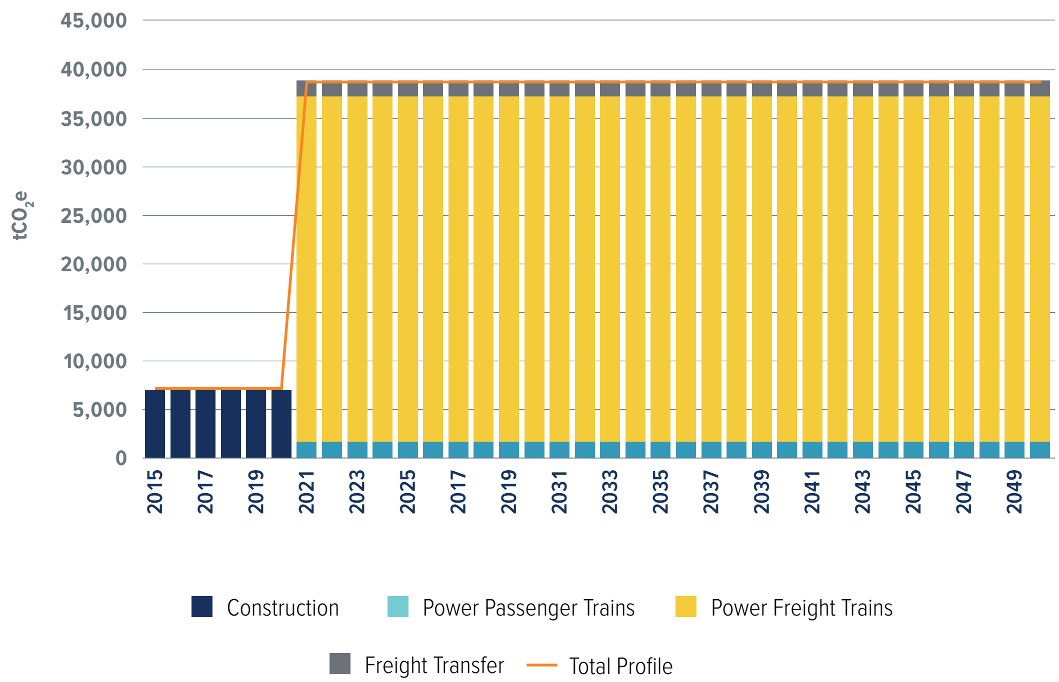


FIGURE 24: EMISSIONS FROM FREIGHT TRAINS, ACROSS THE LIFETIME OF THE NEW 400 KM AKH RAILWAY, ARE CONSIDERABLY HIGHER THAN FOR PASSENGER TRAINS.



of emissions will come from the materials and construction phases (since there will now be little to no emissions from operations and use), creating a stronger incentive to target these emission sources (Figure 23).

Applying a tax to the use stage would be viable under some conditions. For example, a carbon cost of 5 percent under the medium scenario ($25/t$CO_2$e) could provide a sufficient incentive to shift user behavior in the AKH railway example (Figure 17).

Since many use emissions are related to energy consumption, these are likely to reduce as electrification and decarbonization of the grid increases. A tax targeting operation and use may therefore hold significant opportunities in the longer term. However, since rail is generally a lower-carbon mode of transport than road, it is important to ensure that price increases at the use stage do not result in impacts such as rail ticket price increases that drive passengers to shift to higher-carbon modes of transport such as cars. Figure 24 and Figure 25 illustrate this point. To prevent this outcome, a carbon price may be used in combination with an affordability regulation. This would provide an incentive to the rail company to reduce emissions, but the extra costs of those measures would be absorbed by the rail company rather than passed on to consumers.

Freight trains contribute a significant portion of emissions compared to passenger trains. It may be more equitable to target a tax on freight rather than passenger trains as a tax on these assets could penalise train passengers, who have no capacity to influence fuel consumption and for whom a price rise may cause a modal shift to less expensive but higher-carbon alternatives.

Applying a set tax rate (equivalent to a $/t$CO_2$e) at the point of consumption could also help to reduce the likelihood of carbon leakage. For example, a charge on purchases of cement, regardless of supply origin, would work in a similar way to existing excise duties. The tax could be set in line with science-based targets[54] or legally binding legislation, where it exists (for example, carbon budgets in the UK Climate Change Act).[55] However, a consumption-level tax may be politically difficult to introduce unless revenues can be reinvested in schemes that are popular with the public or deemed carbon neutral.[56] Introducing a green dividend could address this concern. The costs generated

FIGURE 25: EMISSIONS FROM PASSENGER TRAINS, ACROSS THE LIFETIME OF THE NEW 400 KM AKH RAILWAY, ARE LOWER THAN FOR FREIGHT TRAINS.

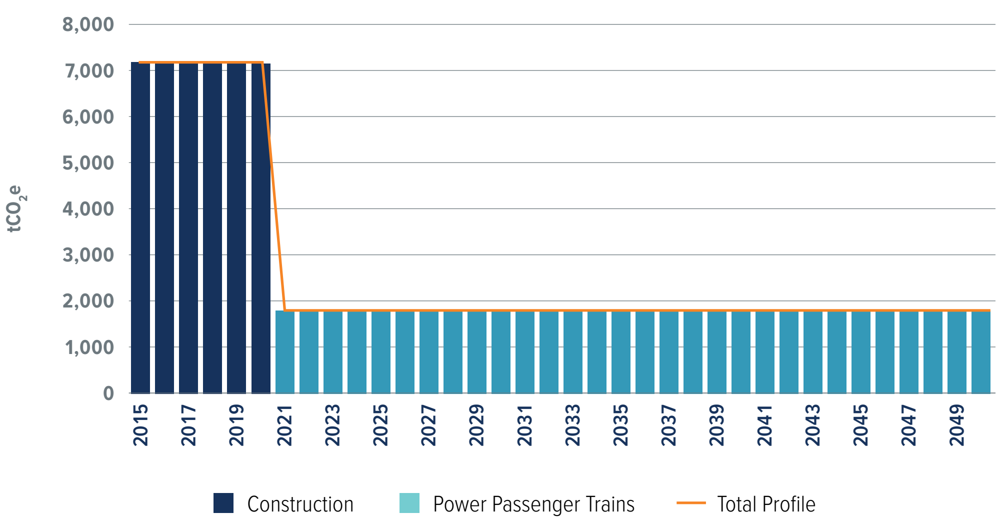
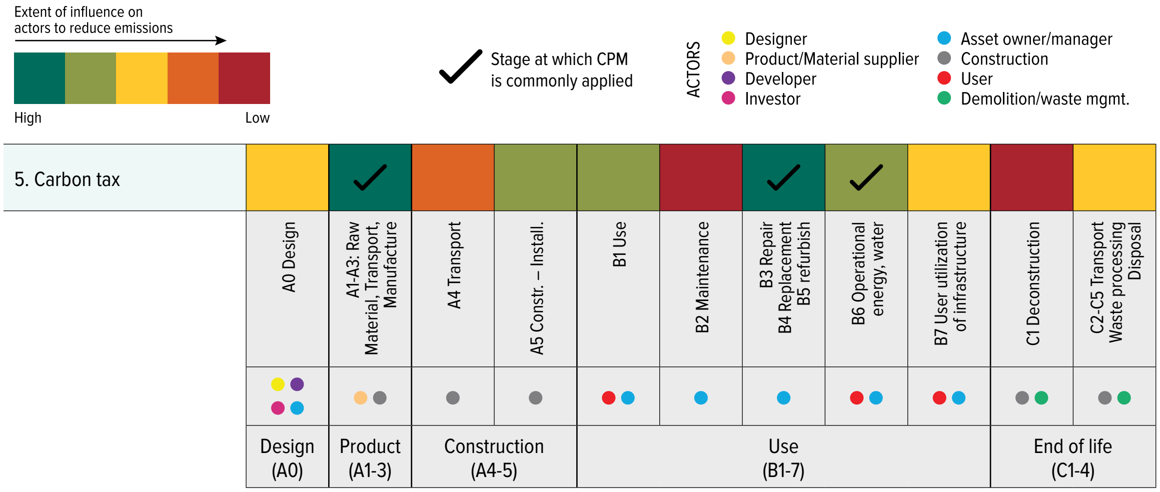


FIGURE 26: HEATMAP ILLUSTRATING THE IMPACT OF CARBON TAX ON THE CVC.



through the tax would be recuperated through spending on green goods and services. For example, a user pays $X on their energy bill but receives 90 percent of this tax back to spend it on green services or products such as installing insulation. Alternatively, a lump sum payment could be given to households. In some circumstances it may be preferable not to attach a rebate to green retrofits. For example, if the sum is insufficient to cover the full cost of a retrofit, the dividend may go unused.

The management of certain assets restricts the application of a carbon tax. Applying a tax to the owner/developer of public infrastructure assets, for example, would be pointless as they are commonly owned and operated by a public body.

Summary

Because a carbon tax is simpler and cheaper to implement and enforce than other types of CPM, it may be better suited to lower- and middle-income economies. A blanket carbon price could be applied across multiple CVC stages, as shown in Figure 24. However, a tax applied on evaluation of the carbon emission credentials of a whole project/asset could influence a greater range of actors than a tax applied at individual stages, which would not influence actors upstream.

A carbon tax on the CVC could be applied across multiple types of use emissions, shifting the common application of taxes from production- to consumption-based emissions. However, while this may be efficient in achieving a set emissions goal, it may also be politically difficult to implement and inequitable, particularly at the use stage since this could disproportionately disadvantage certain groups such as people on lower incomes. Green dividends could be issued to consumers to reduce this negative impact.

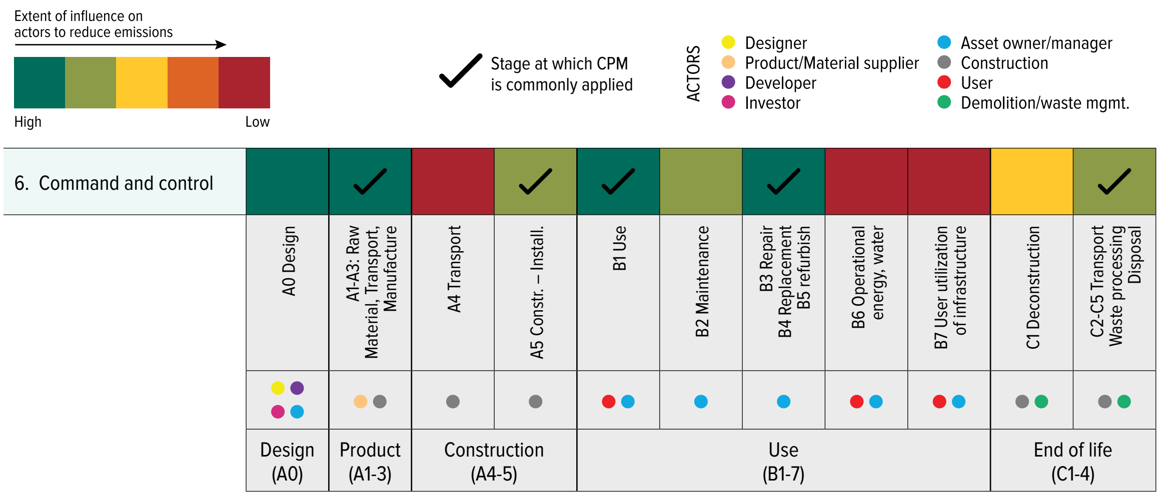
A carbon tax has the benefit that it can be set low initially (as in South Africa). This familiarizes business and individuals with the tax before it increases over time. The approach may, however, limit the mechanism's ability to reduce carbon emissions to levels required by national and international climate targets. As discussed above, carbon taxes can also be used in combination with other instruments to help share the burden and introduce stricter CPMs in the future.

Command and control mechanism

Command and control regulations are compulsory policies that stipulate actions and penalties for non-compliance. A range of carbon pricing regulations could be applied, some flexible (such as a carbon tax or ETS) and others more prescriptive (such as emission limits, performance standards, or a ban on using certain materials or fuels). In this study, command and control regulations refer to the more specific regulations.

Although not strictly considered to be a CPM, command and control mechanisms in the CVC could help regulate new markets and minimize inequitable burden shifting from misaligned incentives. For example, if a house is designed with poor insulation, the inhabitant (who may not own it) will face higher

FIGURE 27: **IN THEORY, A COMMAND AND CONTROL MECHANISM HAS CONSIDERABLE POTENTIAL TO INFLUENCE ACTOR BEHAVIOR, RESULTING IN EMISSIONS SAVINGS ACROSS THE CVC. IN PRACTICE, THERE ARE OBSTACLES THAT MAY MAKE THIS APPROACH LESS VIABLE.**



heating bills and emissions. This was observed in The Village case study, where the application of a $25/tCO$_2$e CPM added $39 a month to energy bills for an average consumer. For a higher consumption (and often poorly insulated) household, this would be unaffordable. Regulation could help reduce this impact. It could also be used as a non-price-based instrument to raise awareness around efficient products and services such as insulation.

The heatmap in Figure 27 indicates that command and control mechanisms could significantly influence emissions reductions because they are compulsory. However, this approach may not be the most cost-effective as it does not take into account that different users have different abatement costs. The approach also does not drive innovation as it incentivizes the fulfilment of minimum requirements instead of best practice. In the CVC, performance standards and limits may provide an effective way of guaranteeing a certain result, such as a fixed limit carbon saving for a given technology. Performance standards can also be used in combination with other solutions, for example, in the case of the UK carbon price floor, a standard was imposed that ruled out new coal generation to support the floor price.

Tradable performance standards may also help ease some of the welfare and political acceptability concerns associated with other regulations. These standards require an average performance level across a sector. High performers can generate permits to sell to lower performers, encouraging innovation (such as a carbon tax or ETS). Yet unlike a carbon tax or ETS, the system only prices the emissions above the average required performance level.

Command and control mechanisms can be applied across a range of economies, although inconsistent standards could result in unintended consequences. For example, if high-income countries restrict certain manufacturing methods that result in high emissions, business could move their polluting practices to lower-income nations.[57] Governments must ensure that command and control mechanisms align with international practices.

To apply command and control regulations to the CVC, target levels for whole-life carbon on projects could be imposed at the planning stage. This would require designers to report whole-life carbon emissions and surpass targets established using benchmark data from preceding reporting years. Such targets and regulations could be delivered through strategic local planning like the London Plan (which requires schemes to assess whole-life carbon and propose reductions) and integrated with carbon offset fund payments to local districts/boroughs.[58] This approach would effectively place a locally determined price on whole-life carbon and provide an appropriate incentive to reduce emissions in a command and control form.

Summary

Command and control regulations are effective in delivering a stated objective such as a strict emissions limit or energy performance standard, but lack the flexibility and market benefits of emissions trading and hybrid solutions. Performance standards can support price-based instruments by creating a minimum requirement and ensuring actors are aligned. Command and control mechanisms can also be phased in gradually, allowing actors in the CVC to prepare for more stringent regulations. However, as regulatory instruments they do not encourage innovation beyond the level required by the regulation or standard.[59]

Command and control mechanisms can be implemented in any market, though it may take time for a regulation to be designed, verified, and approved. Overall, they are likely to be simpler and cheaper to introduce than a market mechanism. A standard can be applied at any stage of the CVC, including operations or use, where a large proportion of emissions are produced.

While command and control options are by themselves fairly rigid and targeted, in combination with other CPMs or policy (for example, ETS with performance standards), they provide a more flexible means to capture both upstream and downstream emissions.

Discussion

The case study analysis explored the potential and impact of applying common CPMs to the CVC, while also identifying the constraints that emerge when they are applied to a diverse and complex sector. This section discusses these issues and what they mean for more effectively integrating the CVC in CPMs.

CARBON PRICE

The case studies show that, at the low price threshold ($10/t$CO_2$e) in high-income country scenarios, the carbon-related costs are small enough to be absorbed by the polluter or passed on in a way that is affordable to downstream CVC actors and their customers. However, the medium ($25/t$CO_2$e) and particularly the high carbon price threshold ($53/ t$CO_2$e) have the potential to trigger changes in the behavior of both polluters and downstream actors in the CVC to reduce costs.

The findings suggest that simply raising the carbon price within existing CPMs may bring about the refocus needed to change behaviors in the CVC to deliver low-carbon buildings and infrastructure. Whether or not this is possible in political and practical terms depends on the context. But if carbon pricing is to meaningfully contribute towards meeting the Paris Agreement goals, then prices across all sectors will need to rapidly increase.[60]

TARGETING BEHAVIORS OF PROJECT FUNDERS, DEVELOPERS, AND DESIGNERS

In the CVC, CPMs commonly target the construction materials manufacturing stage and the operation and use stage of assets. By targeting these stages, CPMs miss the CVC actors associated with the early stages of projects, including funders, developers, and designers. This is justified on the basis that these actors have marginal direct carbon emissions, and their activities tend to fall under the emission thresholds of operating CPMs.

However, this also represents a failure in the way the mechanisms are designed and function. In practice, many of these actors retain significant power and influence over a project's whole-life carbon emissions by defining the material supply chain, operational, and in-use carbon emissions outputs.

To reduce total emissions associated with an asset's entire life cycle, an effective CPM needs to influence the early stages of project-making (for example, funding, brief development, and design), as this is where project carbon ambitions are set and decisions made that affect the rest of the CVC. This could be achieved by setting a higher carbon price, as discussed above, or placing the constructed asset in the CPM.

PUTTING THE CONSTRUCTED ASSET IN A CPM

Traditionally, CPMs aimed to capture emissions from large-scale, high-carbon sectors such as power stations and industrial plants. As discussed above, these approaches fail to cover the early stage processes where critical decisions are made. Including constructed assets within CPMs would help capture CVC emissions in a more complete way. Depending on the approach, the CPM might extend in scope to include everything from the asset's constructed embodied carbon emissions, to those arising from its operation and use over its service life, as well as emissions from end of life and final waste treatment.

Addressing emissions across this scope would be exceptional given how most construction projects consider carbon emissions. However, standardized methodologies exist for determining construction asset life-cycle emissions, and if combined with a CPM at the point of project realization, they could incentivize project-making actors to address project emissions or face pricing penalties.

Given their size and function, buildings and many forms of civil infrastructure generally emit much less carbon than industrial facilities or power stations. For this reason, the CPM would need to significantly lower the emission entry level threshold. Furthermore, in order to easily compare buildings, the measurement impact would be per unit of service provided, for example per square kilometer of floor space per year. By implication, this would also mean that schemes would open up to a much wider target base. For example, a country might have many hundreds of power stations captured by a CPM. However, a scheme that placed new buildings under its jurisdiction would likely extend to hundreds of thousands, and even millions of assets (particularly if operational/user emissions from existing buildings were included).

With further design, the CPM could also be effectively applied to existing built assets, thus helping to capture emissions from their operational stage. This would broaden the impact of the CPM and encourage a shift to emissions performance across the building stock.

DEALING WITH OPERATIONAL AND USER CARBON

Evidence from analyzing the four case studies shows that across the asset classes considered in the study (infrastructure – road and rail, and buildings – commercial and residential), the vast majority of emissions are generated during the operation and use phases of the asset's life, as shown in Figure 28 and Figure 30.[61] However, existing CPMs tend to focus on the product and construction stages (Figure 29), reflecting the "polluter pays" principle.

More emissions need to be captured from every stage of the CVC. While tackling operational emissions is crucial in the short and medium term, as the world electrifies and decarbonizes, the significance of operational emissions (largely related to energy and fuel) will decrease relative to materials (that is, embodied energy).[62] To be effective and sustainable over the long term, CPMs need to incentivize actors from designers downwards to improve efficiency at all stages of the CVC.

FIGURE 28: USE STAGE EMISSIONS CONSTITUTE A SIGNIFICANT PROPORTION OF TOTAL PROJECT EMISSIONS ACROSS THE FOUR CASE STUDIES.

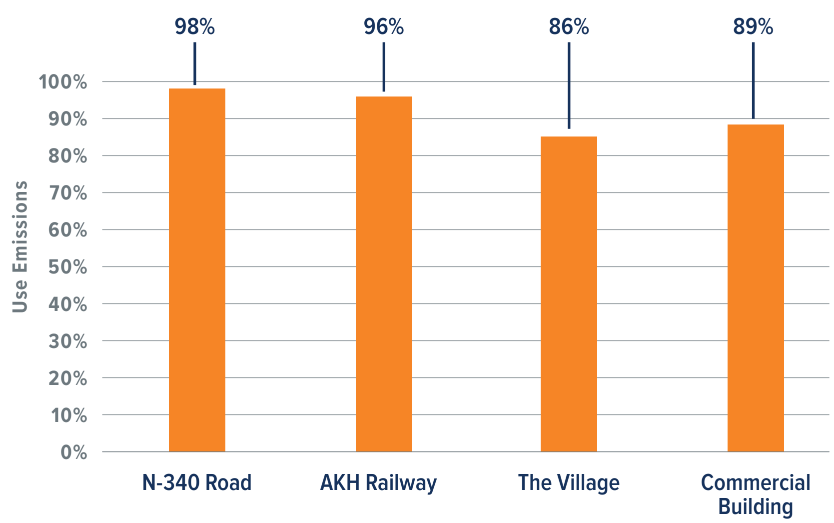
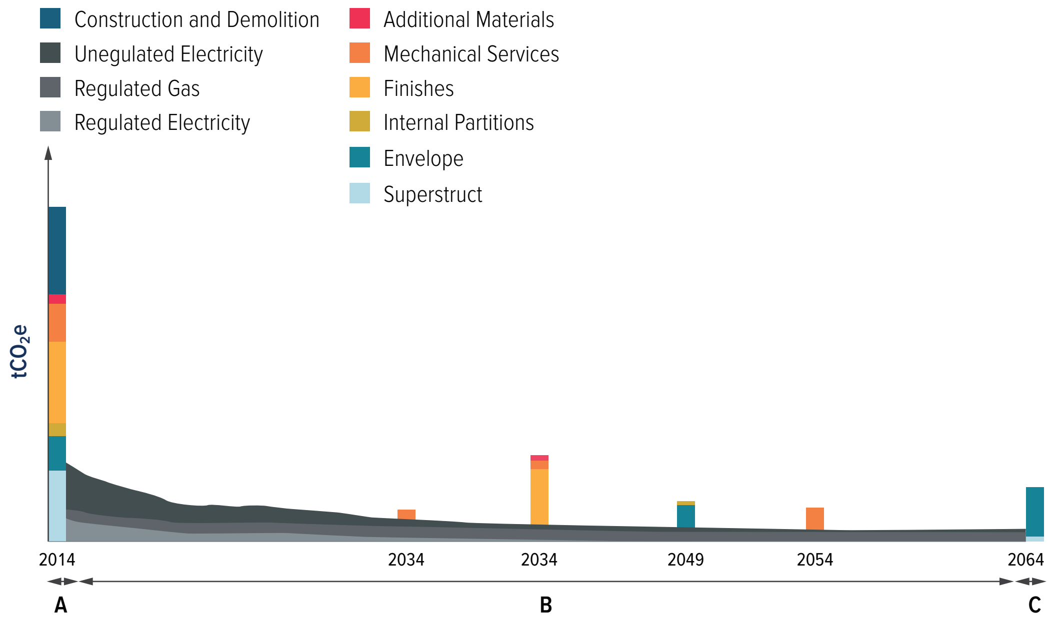


FIGURE 29: LIFE-CYCLE EMISSIONS PROFILE FOR A COMMERCIAL BUILDING, SHOWING THAT WHILE EMISSIONS AT STAGE A (MATERIAL MANUFACTURE) ARE HIGH, EMISSIONS FROM STAGES B (CONSTRUCTION) AND C (OPERATION AND USE) ARE ALSO SIGNIFICANT AND MUST BE ADDRESSED.



CVC IN MARKET-BASED CPMS

Market-based instruments can work well for large, industrial emitters, who can accommodate the high levels of administrative oversight needed. Consequently, these mechanisms tend to deliver better carbon reductions in higher- and middle-income economies, which can organize these systems and shoulder associated costs. A tax can be applied more broadly, making it viable in high- as well as lower-income economies, though carbon taxes can be politically difficult to implement.[63]

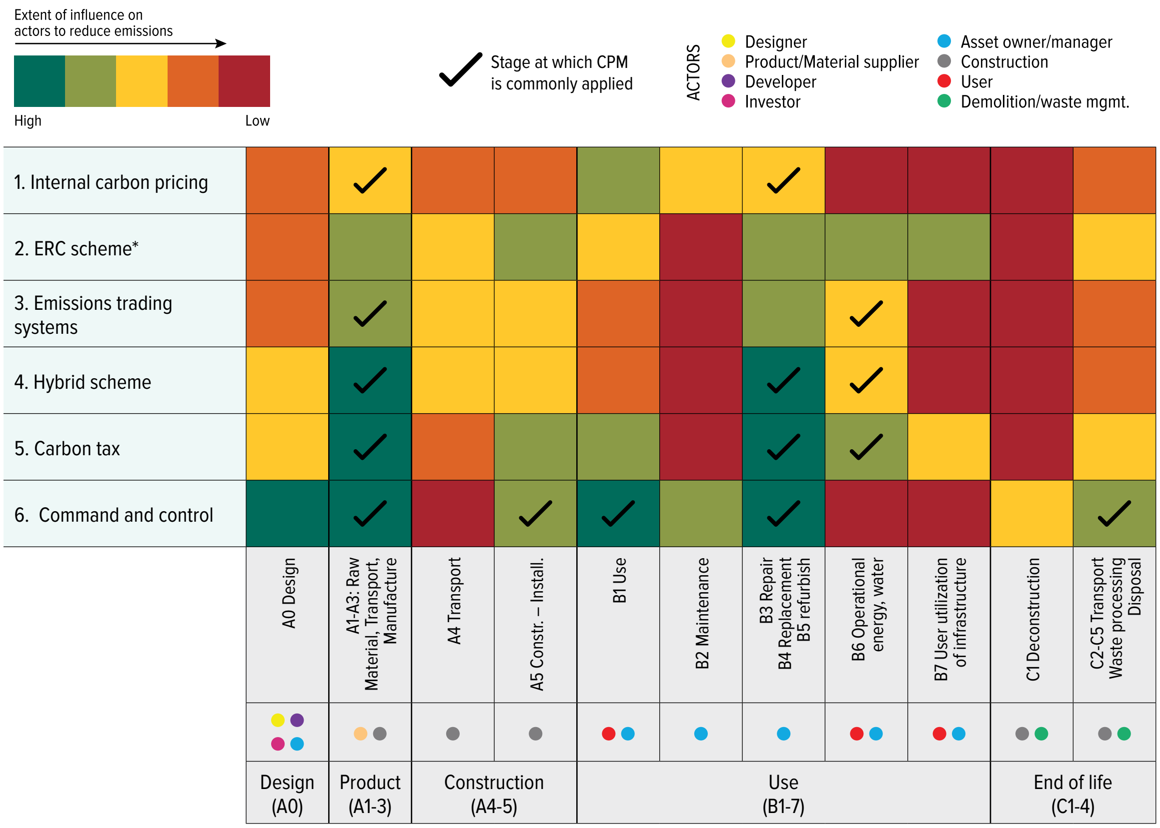
DELIVERY MODEL

Construction project delivery models are diverse, ranging from highly integrated to segmented; integrated models tend to internalize life-cycle considerations (such as low-carbon ambitions) of the CVC more effectively. This is particularly powerful when the CVC retains responsibility for an asset's operation and use.

As such, where low carbon is a priority, an integrated delivery model spanning multiple life-cycle stages will incentivize project actors to look at the full life cycle in a planned, holistic, and balanced way. There may be trade-offs, but the CVC will be incentivized to optimize the project for a low-carbon outcome because it is accountable for emissions at all life-cycle stages.

It is also important to note that the project delivery model may vary from project to project. A jurisdiction using a CPM cannot dictate which model the CVC will use, and any CPM will need to have the flexibility to work across different delivery models. On this basis, no particular challenges associated with specific types of CPMs are identified and the full range of segmented to integrated delivery models are widely applied in markets using the six generalized types of CPM.

FIGURE 30: HEATMAP ILLUSTRATING IMPACT OF CPMS ON THE CVC. THIS VISUALIZES THE SCOPE AND IMPACT OF CPMS WHEN APPLIED TO THE CVC AND SHOWS THE COMPARATIVE IMPACT OF THE SIX CPMS ON THE CVC.



*An ERC scheme often requires the sustainability of the whole project to be evaluated and is therefore not placed in one particular stage.

MANAGING DOWNSIDE RISKS

As with any new mechanism, there is potential for unintended outcomes. In the CVC, for example, applying a CPM could drive materials production to regions without such regulations. It could also increase relative costs of low-emission forms of transport against baseline costs and discourage the selection of this mode of transport over a higher-emitting one.

More critically, there is a direct link to social benefit (such as the development of hospitals, schools, homes, or roads). For basic-needs infrastructure, the impact of a CPM on affordability and citizen welfare needs to be carefully considered. For example, as the N340 road case study illustrates, it may be inequitable to apply a CPM to users (in this case, drivers on roads) because they have no capacity to influence the asset's design and may struggle to shift to lower carbon modes of transport due to, for example, a lack of alternative transport options.

This indicates that the CPM needs to be clearly tailored to building and infrastructure asset classes. For example, a poorly designed CPM could increase housing costs and lead to higher life-cycle carbon emissions (by, for example, incentivizing single glazing over double glazing alternatives), with particular impacts in lower-income households.

A tailored CPM design is crucial where potentially conflicting standards already exist that any new mechanism would need to align with. Prescriptive design standards may limit the options that designers have to reduce life-cycle emissions; in such cases, shifting to performance-based standards may allow the CPM to target the full range of emission reduction options.

SUMMARY

The evaluation of the case studies demonstrates that no single carbon pricing approach could be applied to all CVC asset classes, scales, and markets. However, regulated CPMs applied at scale will have greater impact than voluntary ones because they are enforceable. Despite this, internal carbon pricing has an important and growing role in helping companies analyze their future climate risks and investment strategies, show leadership, and catalyze low-carbon behavior across their business and supply chain.

Given the diversity of the CVC and its assets, a hybrid scheme is likely to provide flexibility and limit impacts on competitiveness and welfare across the built environment sector. A hybrid scheme could combine a traditional solution like an ETS with a tax or threshold to maximize the capture of emissions from all CVC stages while accommodating certain sectors and avoiding negative impacts on certain groups.

Solutions that increase the carbon price over time may be less effective in the short term but more acceptable to high-carbon industries and lower-income economies, and therefore more effective in the longer term. In some lower- and middle-income countries, this approach will provide additional time to alter processes and behavior. It will also deliver countries' commitments to the Paris Agreement, under the "common but differentiated responsibilities" principle that encourages higher-income nations to take the lead in tackling climate change and allows some less developed economies to curb their emissions more slowly.[64] A well-designed hybrid mechanism is likely to capture and price the carbon emissions across the CVC in a more effective and fairer way than a tax or ETS alone.[65]

The research suggests that in their existing form, CPMs only really influence emissions associated with material production activities and, to an extent, fuel and energy generation, with little focus on the consumers of carbon, that is, those investing in and developing projects, those who are activating emitters in the materials supply chain through design choices, and those influencing operational and user emissions, again through design choices.

It follows that significant reductions in emissions can be achieved by design choices, which could result in direct knock-on impacts on material production emissions. However, the technological alternatives for creating lower-carbon production processes must be in place, or there must be material substitute options available. If not, there is a risk that changing design may significantly increase project costs or affect asset function and performance. In practice, this means effective CPMs targeted at the CVC need to be implemented alongside clear industry targets that drive investment and transition to lower-carbon production processes or material substitutes.

Developing an Integrated Carbon Pricing Mechanism for the Construction Value Chain

Overview

As the research has shown, existing CPMs can be adjusted to expand their scope to better capture the CVC. However, in many cases this will not be practical, and indeed, it may prove challenging to gain the support of those operating established CPMs.

This section sets out ideas and models for an integrated CPM for the CVC. An overview of the concept is shown in Figure 31. At its core, the concept is about placing the constructed asset in the CPM. It might therefore be described as a project-level scheme that incentivizes carbon management early in the project planning stage, with cascading requirements to the wider value chain driven from those ultimately responsible for project-making.

The CPM would be authorized through existing planning approvals/project consenting processes. As such, it would be enforced through jurisdictional construction regulations/building codes, making the project-making actor, that is, the investor, developer, and/or asset owner, responsible for ensuring compliance.

Depending on the extent of the CPM, it needs to be underpinned by standards and protocols for an asset's energy efficiency in operation and use, and a materials supply chain carbon emissions assessment (embodied carbon). This would need to come together within a whole life-cycle carbon accounting framework. The governing jurisdiction would need to provide appropriate direction for this framework.

Depending on the required scope of the CPM, it could be applied to a complete project and its value chain, or targeted to more specific life-cycle stages or actors. For example, and with reference to Figure 31, a CPM that applied a price to a project's carbon emissions, levied at the point of building consent approvals, could target:

- Supply chain emissions (such as the manufacture of products and materials), as required by the project brief, and defined by design response and specification.
- Construction activity emissions (for example, diesel and electricity), as selected by the constructor.

KEY MESSAGES

- An integrated CPM for the CVC at the project scale has the potential to incentivize carbon management early in the project planning stage with cascading requirements for the wider value chain. This places the constructed asset within the CPM. It would be authorized through existing planning approvals/project consenting processes and enforced via jurisdictional construction regulations/building codes.
- The integrated CPM could apply as a blanket carbon price, where the project carbon emissions are determined for all relevant elements and a carbon price is applied to every ton of emissions, or as a threshold carbon price, where a carbon price is applied to every ton of carbon emitted over a defined threshold.
- Existing carbon management frameworks may also be used to monitor, report, and capture life-cycle emissions, for example PAS 2080: 2016 Carbon Management in Infrastructure.
- Revenues from the scheme may be collected and reinvested in industry schemes to develop and demonstrate green innovations or fund low-carbon infrastructure. Alternatively, a green dividend may be established, which rewards individuals and companies for early investment in low-carbon options.
- The new CPM would need to align with and respond to existing global carbon markets, including their structures, prices, and regulations, without creating double counting, uncompetitive outcomes, or disproportionate burdens for some participants. Border tax adjustments and other mechanisms may be applied to avoid these outcomes.

FIGURE 31: A CONCEPT FOR AN INTEGRATED CPM THAT PLACES THE CONSTRUCTED ASSET WITHIN THE CPM AND, BY IMPLICATION, THE ACTORS RESPONSIBLE FOR ITS DEVELOPMENT, DESIGN, CONSTRUCTION, AND OPERATION.

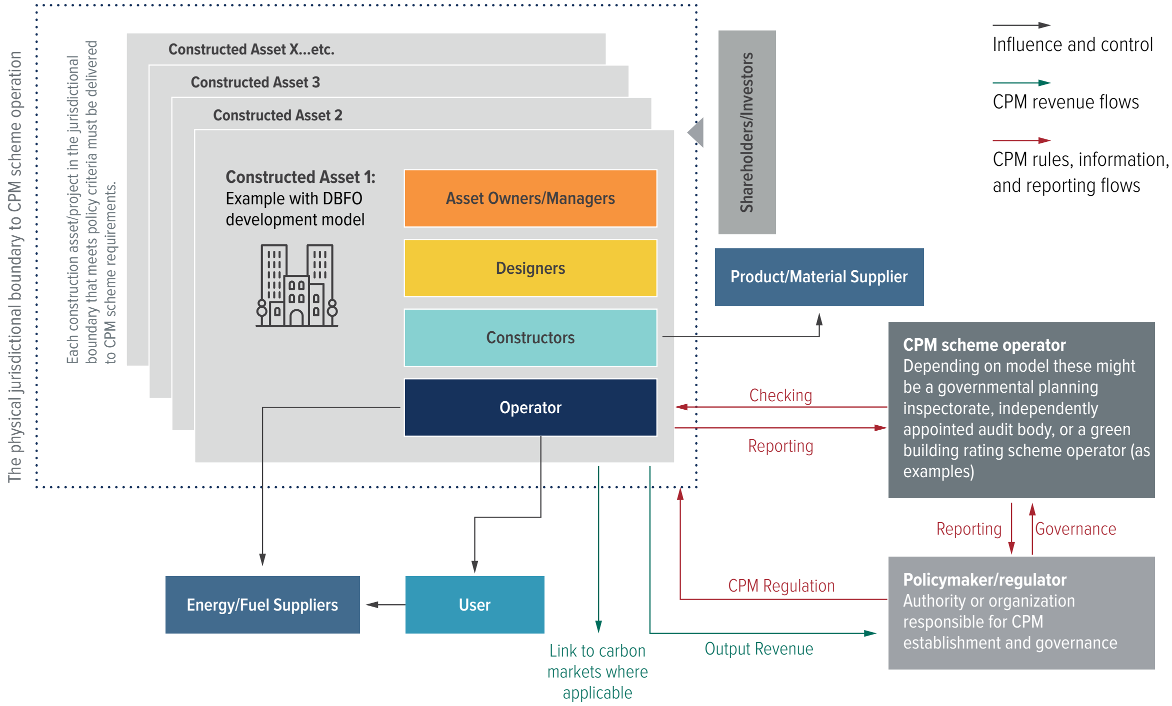
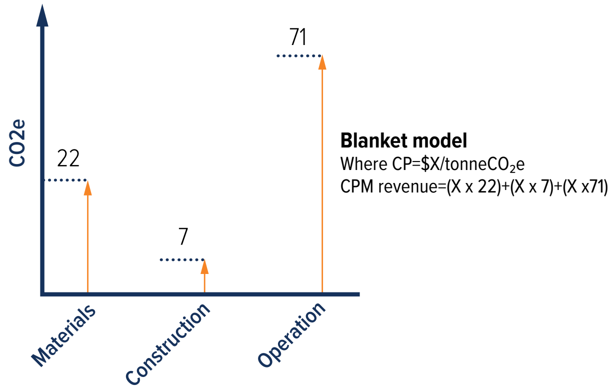


FIGURE 32: UNDER THE BLANKET MODEL, THE REVENUE GENERATED IS THE CARBON PRICE MULTIPLIED BY THE SUM OF THE CARBON EMISSIONS PRODUCED AT EVERY STAGE IN THE CVC.



- Regulated energy in operation (for example, electricity, gas, and oil), as demanded by the asset operator.

Although not shown in Figure 31, variations of the concept might extend to include user-related emissions.

These strategies can in part be achieved by different models through which the carbon price is applied to the project. Two potential mechanisms are a "blanket" CPM and a "threshold" CPM.

Blanket carbon price: Where the project carbon emissions are determined for all relevant elements and a carbon price is applied to every ton of emissions. This concept is summarized in Figure 32.

Threshold carbon price: Where a carbon price is applied to every ton of carbon emitted over a defined threshold. Here, revenue generation is a function of the difference between the aggregated emissions of material supply, construction, and operations; and the jurisdictional CPM threshold level. This concept is summarized in Figure 33. Variations of this model may exist, where different thresholds are set for:

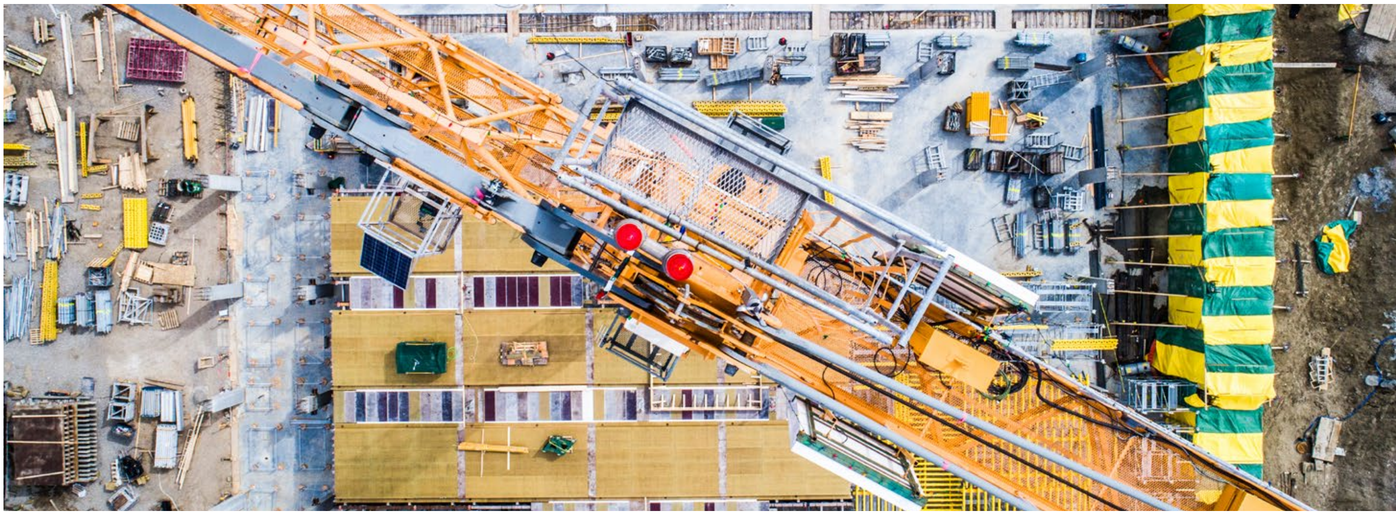
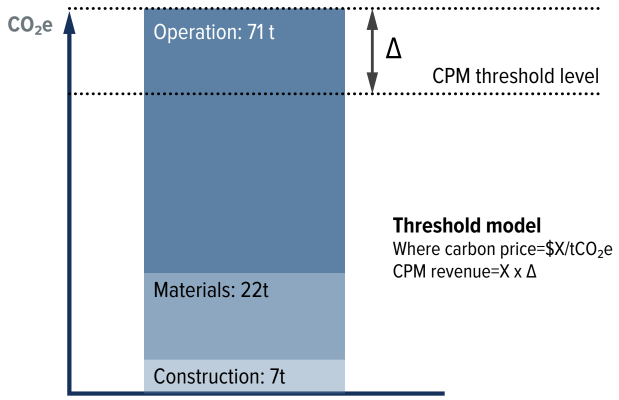


FIGURE 33: UNDER THE THRESHOLD MODEL, THE CARBON PRICE IS ONLY APPLIED TO EMISSIONS PRODUCED OVER A SET THRESHOLD.



- Discrete life-cycle phases (material supply, construction, and operations).
- Developments of different sizes or projects of different asset class.
- Different levels of operational performance.

Governance

The pricing mechanism will be defined by jurisdictional boundary (such as national or local government), with governance overseen by government agencies/regulators. In this way, the CPM would be mandatory for those seeking permission to build within the jurisdiction. Certain sectors (such as education and social housing) may be exempted, pending evaluation of socioeconomic and political impacts. The governmental level at which this would be implemented would depend on political priorities and the capacity of such organizations to oversee the process.

A real-estate or asset portfolio owner (such as a health authority, highways authority, or commercial real-estate provider) might voluntarily choose to apply the mechanism to their development program to manage carbon across their asset portfolio. Whether on a mandatory or voluntary basis, the authority responsible for the jurisdictional scope of the CPM would govern directly or set up a governance system to oversee CPM application in its jurisdiction.

Governance systems have different validation and accountability procedures in place, including regular auditing, self-disclosure, spot-checks, and third-party accountability. Which procedures are employed will depend on factors such as internal capabilities and cost.

Governments often adapt their governance frameworks for such schemes as they develop, in an effort to streamline the approach and improve accountability. For example, the UK government recently introduced a new mandatory framework for large companies to report energy consumption (Streamlined Energy and Carbon Reporting framework), replacing the CRC energy efficiency scheme.[66] This new framework requires companies to report directly to the scheme, rather than the previous spot audits and self-certification[67] process, which carried a significant burden for the UK government's Taskforce on Climate-related Financial Disclosure.

Operation

A CPM scheme operator would be appointed or established by the jurisdictional governance authority. Options might include:

- The relevant planning inspectorate.
- An accredited organization (such as a certification or verification body).
- A green building rating scheme operator.

The scheme operator would be responsible for verifying each applicant project within its jurisdiction, evaluating its carbon emissions and CPM accounts, including credits awarded and money paid. The project-making party or their representative would prepare project accounts. The scheme operator would prepare periodic summary reports to the CPM governance authority. Submission to the CPM would be made at the point of planning application (pending consent to build). The project maker would thus be obliged to provide evidence to demonstrate how their project would meet carbon reduction objectives over its lifetime.

The CPM would be administered, and revenues generated, based on a reported carbon output within a specified time period. Fines could be imposed at project completion if a project fails to deliver on its planned undertakings. The methodology for reporting/accounting may be determined by the governance authority overseeing the scheme.

In lower-income markets where there may be limited expertise/capacity within planning authorities, it might be more practical to integrate the CPM with light-touch rating schemes such as EDGE than to incorporate it into the existing planning system. This approach would also need to consider potential conflicts with existing certification bodies. These bodies use transferable models applicable in multiple jurisdictions, so assuming local circumstances and regulations are taken into consideration, there should be no conflicts, for example, ensuring taxes are collected and managed by local government, not the accreditor.

Revenue

Revenue from the scheme may be collected and used in several ways. In mature markets,

revenue gathered should be reinvested in industry schemes to develop and demonstrate green innovations, rather than going into overall government budgets. This could be a closed fund that promotes sustainable innovation in the industry through research and development, for example. This could help increase and sustain research and development even in downturns when margins are tighter.

An alternative approach could be a green dividend, whereby individuals and companies are rewarded for early investment in low-carbon options. There is a risk that those already engaging in best practice would be rewarded, for example, if UK timber-framed housebuilders were given a substantial dividend at the expense of those using brick and block. However, this kind of scheme would also signal to the market which approaches are government-supported. Green dividends have been more successful at the smaller community scale, for example, residential developments to incentivize homeowners to change behavior.

In lower-income economies, revenue could be collected into a fund for investment in low-carbon infrastructure. This could more effectively maintain infrastructure investment in regions where government revenues are limited. To some extent, it could also help ensure infrastructure investment keeps pace with commercial development, as fees would be paid on such development that could be reinvested in the infrastructure that is needed to support them.

Reporting

Accounting for carbon within the CPM would be undertaken using existing CVC protocols:

- For products (including materials): BS 15804: 2012+A1: 2013 – Sustainability of construction works.[68] Environmental product declarations. Core rules for the product category of construction products.
- To calculate construction emissions, the CPM would use estimating protocols such as RICS Surveyors Construction Handbook to determine the site-based emissions, as well as the traditional program of works and bill of quantities, which include contractor estimates of build time, fuel, and labor costs.
- To align with operational phase carbon emissions and sensitivities around pricing carbon on future performance, the CPM would use protocols such as display energy certificates[69] or the National Australian Built Environment Rating System[70] to verify carbon output in asset operation.

Existing carbon management frameworks may also be used to capture life-cycle emissions, such as PAS 2080: 2016 Carbon Management in Infrastructure.[71] This could provide an effective framework through which a project could report to the CPM. For buildings, the RICS Professional Statement on Whole Life Carbon Assessment for the Built Environment[72] or other interpretations of EN 15978: 2011 Sustainability of Construction Works might be used. The scheme operator might also administer the CPM using a model based on existing green building rating schemes. LEED,[73] EDGE,[74] and CEEQUAL[75] could all provide platforms for the management, verification, and reporting of projects under the CPM. The platform or framework chosen would depend on what a given government deems most appropriate for their jurisdiction, which may be determined by current uptake rates, understanding of the framework, alignment with current strategy/regulation, and other priorities.

Reporting operational emissions

Where operational emissions are included in the delivery method a project uses (for example, in a DBFOM), the asset owner or developer is involved in all stages of the life cycle, including the eventual operation of the building. In this scenario, operation stage emissions could be calculated using the frameworks described above, in addition to schemes such as the National Australian Built Environment Rating System, display energy certificates, or equivalent local schemes.[76] A carbon tax could then be collected on an annual basis. This approach would also work for a building where the initial developer was not the same as the eventual operator. In this case, two revenue streams could be collected:

- From the asset owner/developer for the materials and construction of the building.
- From the operator on an annual basis for emissions produced through operation, such as fuel consumption.

This approach could also extend to cover operation emissions, either with a levy at the point of construction or an annual tax based on the building's display energy certificate or equivalent.

Relationship with wider carbon pricing markets

Any new CPM would need to align with and respond to existing global carbon markets. It would need to be sensitive to their structures, prices, and regulations without creating double counting, uncompetitive outcomes, or disproportionate burdens for some participants. For example, consider a cement manufacturer that supplies cement to a project. The cement factory is located in a jurisdiction outside the one where the CPM originates. Carbon costs must therefore be adjusted for the cement factory in its production jurisdiction by:

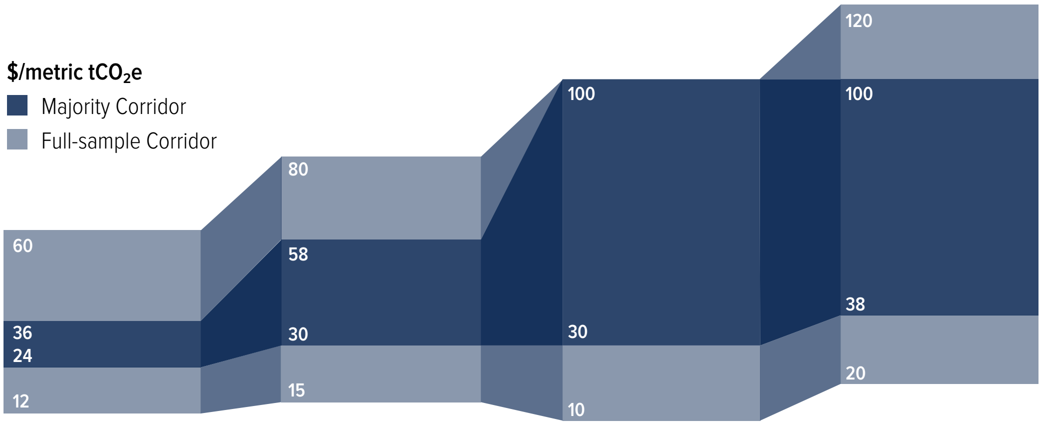
- Applying a cost to the carbon arising from the cement based on the difference between the carbon price in the production jurisdiction and the project CPM; or
- Awarding the project a carbon credit where the production jurisdiction CPM is higher than that applied to the project.

In the case of a blanket CPM, adjustments would be made to each project's carbon inventory, while for a threshold CPM, resulting adjustments would be made to each project's carbon inventory before reviewing how the scheme performs against the assigned threshold level. Details of three potential scenarios can be found in the Appendix.

This approach is similar to border tax adjustments, which despite having the potential to conflict with World Trade Organization regulations, could also help to create a level playing field and minimize impacts on competitiveness.[77] To ensure market stability and minimize regulatory burdens across national jurisdictions and industry sectors within the value chain, it would be important to align potentially overlapping programs. This would also support competitiveness and avoid segmenting markets and simply shifting where emissions occur in an economy. Such alignment would need to be carefully considered given geographical contexts and would need to facilitate local (for example, city or regional planning authority), national, and international synergies. As discussed above, linking schemes across jurisdictions may be one way to solve this.

In Scenario 3 (see the Appendix), the project or supplier is in credit with the scheme, allowing the asset owner or developer to transfer assets to other projects within their portfolio. These credits are not intended to enter a tradable market with other asset owners/developers, but instead to encourage low-carbon developments across the sector. The credits may

FIGURE 34: CDP'S CARBON PRICING CORRIDORS PROVIDE A BENCHMARK FOR BUSINESS AND INVESTORS MAKING STRATEGIC DECISIONS CONSISTENT WITH A LOW-CARBON ECONOMY.[84]



accumulate over time; however, as the carbon price in both the blanket and the threshold model might be delivered in a carbon price corridor plan (Figure 34) – which escalates the carbon price for a designated sector or sub-sector to reduce emissions – these credits will likely be used as the threshold drops or the blanket price increases.

Alternatively, a time limit could be set on the use of credits to prevent the front-loading of reductions to obtain credits in anticipation of future price rises. This would drive developers to maintain best practice operation and develop innovative assets over the medium term. A limit on the use of credits, or a clear increase in price, is needed otherwise there would be no incentive for developers to innovate.

These credits can be awarded through two potential approaches. In the first approach, the asset owner or developer is solely responsible for project emissions. For example, if a material supplier has paid a higher carbon price, as shown in Scenario 3 (Table 7 in Appendix), then the asset owner/developer will be awarded credits. The supplier may reclaim the costs paid by placing a higher cost on its materials or choose to absorb this cost but create a more favorable product that will result in the asset owner paying less or no carbon cost for their project.[78] For project development models where the asset owner or developer is not solely responsible for project emissions (such as Build-Transfer), the credits could be awarded to the supplier, lowering their costs on other imported materials.

The benefit of moving away from a carbon market approach, which allows suppliers or project developers to trade with other similar actors, is that it reduces the likelihood of companies shifting production to countries with a lower carbon pricing regime, because they will still be required to pay a price on importing or constructing in jurisdiction A.

Ideally, this concept would be developed alongside a suitable client or stakeholder such as government estates that commission work through multi-year partnerships/frameworks and operate assets for a prolonged period. This would allow credits to be transferred and used across multiple projects and give designers/suppliers an opportunity to develop alternative solutions over a series of projects. This is discussed further in the next section.

Moving Forward

Adapting existing CPMs for the CVC

Applying CPMs to the CVC presents both challenges and opportunities. This study proposes several options for adjusting established mechanisms to better capture CVC emissions. The following section summarizes the most important observed opportunities and suggests areas of future research.

INCLUDE BUILT ASSETS IN EXISTING CPMS

CPMs tend to target emissions from large-scale facilities such as materials manufacture, and some activities related to operation and use. While this approach successfully captures a significant proportion of life-cycle emissions, it does not comprehensively target emissions from every stage of the CVC. To do so, it is critical that CPMs incentivize the consideration of low-carbon priorities from the start of a built asset's life, embedding it in design and procurement decisions, where carbon emissions are locked in for the duration of an asset's life.

One way of achieving this is for whole assets such as buildings to participate in CPMs like ETS. Under this approach, standardized methodologies may be used to determine the life-cycle emissions of the construction asset, combined with a CPM at the point of project realization, to incentivize project-making actors to address project emissions or face pricing penalties. Scheme operators would

KEY MESSAGES

- Allowing built assets such as buildings to participate in CPMs would enable the capture of emissions across the asset's life, from constructed embodied carbon emissions, to those arising from operation and use, as well as those from end of life and final waste treatment.
- Flexible solutions such as hybrid mechanisms that combine elements of established CPMs can provide adaptability while easing the burden on welfare and competitiveness, making them appropriate to various asset classes, project scales, CVC delivery methods, and economy types.
- To reduce emissions throughout the CVC, carbon prices need to increase to levels that cannot simply be absorbed or passed on without any change in behavior. Action from governments and the industry is needed to deliver this change.
- With further research and some adjustment, many of the CPMs reviewed in the study can be applied to the CVC to more effectively capture emissions from across the value chain. Industry and regional collaboration will enable greater efficiencies and coordination.

need to make adjustments to allow buildings to participate in the ETS, and update and apply regulatory measures to incentivize the appropriate behaviors.

Because ETS are already widespread and well established in various locations, exploring the potential to expand such schemes to include CVC assets is recommended. Putting built assets into such schemes may also be a viable and relatively acceptable option to industry and consumers.

APPLY FLEXIBLE OPTIONS

Given the complexity and variation across the CVC, there is no single CPM solution that suits all circumstances and markets. However, in many markets, a hybrid solution that combines a market or regulatory mechanism with a floor or threshold price may provide the flexibility needed to maximize the capture of emissions while easing the burden on welfare and competitiveness. It could also help to minimize price volatility, which would appeal to investors and governments.

A carbon tax may be applied in combination with an ETS at various points along the CVC. This would limit carbon reductions to a certain level and generate revenues that may be reinvested in decarbonization measures or redistributed to users via a green dividend. Alternatively, a tax may be added, for example, at the point of consumption for certain high-carbon products.

With careful assessment of the potential impacts of such strategies, a hybrid solution could provide the adaptability needed to accommodate variances in asset class, project scale, and CVC delivery method.

INCREASE THE CARBON PRICE

Fears over carbon leakage and competitiveness have led governments to intervene in schemes' functioning by, for example, allocating free allowances to high-carbon industries or keeping carbon prices low. These actions reduce the impacts of CPMs.

To truly capture emissions from across the CVC, prices will need to increase gradually over time, to levels that cannot simply be absorbed or passed on without any change in behavior. While it is unlikely that actors in the CVC will push for such changes individually, there needs to be a concerted effort by governments and the industry as a whole to apply carbon prices that affect behavior. Higher carbon prices would undoubtedly drive more efficient emissions reductions.

While there are legitimate reasons for allocating allowances to carbon-intensive and trade-exposed industries, research suggests that the impacts on these industries may have

been overestimated.[79] In higher-income economies, it is essential that these prices increase soon, while in lower-income economies, as shown by the South African case study, it may still be acceptable, though not ideal, to implement low prices (of about $10/tCO_2e$), with a structured and transparent plan to increase them over time.

SUMMARY

The most appropriate CPM in a given location or context will depend on a range of factors. For example, emissions trading requires complex structuring and oversight, which is costly and time-consuming. This may make it better suited to geographies and markets where relevant regulatory structures are or could be established and high administrative costs can be absorbed by the market. Taxes may be politically challenging to implement but better suited to certain sectors such as fuel, where the potential for decarbonization increases effectiveness, as opposed to a sector like cement, which faces more complex challenges in lowering its emissions.

The choice of project delivery method will also influence how emissions may be reduced over an asset's life cycle. In many cases in the CVC, an integrated approach like DBFOM may be used to incentivize all parties (designer, builder, investor, and operator) to maximize carbon reduction at every stage.

Welfare and equity issues are also critical considerations, especially in emerging economies. CPMs must make allowances or compensate for impacts on vulnerable groups likely to be affected, such as poorer households less likely to have the capacity to implement energy efficiency measures that have little or no potential to change their behavior. It is also important to evaluate the potential for unintended consequences, for example if a CPM on rail use increases prices to unaffordable levels and triggers a modal shift to cheaper, higher-carbon transport such as individual vehicles.

Businesses are already starting to understand the benefits of implementing internal carbon prices. The construction industry needs to commit to more advanced efforts to curb its emissions (such as applying internal carbon prices, and reporting climate risks and impacts) and work more closely within and across sectors. This could involve sharing information on challenges and solutions. Change is already under way; platforms like the CPLC can facilitate and drive such activities.

Governments and companies must carefully weigh the potential impacts against the benefits, providing solutions to help those who cannot easily alter their behavior while challenging those who can through stricter targets and penalties. By working with their regional and international counterparts, schemes may also be linked, thus creating a level playing field and minimizing threats to competitiveness.

As more economies implement carbon pricing, international cooperation will play a critical role in aligning prices across borders, minimizing the potential for carbon leakage and overcoming concerns around competitiveness. This will create opportunities to share experiences and lessons learned and potentially to link trading schemes. Economies are already aligning with other policies and global efforts such as the Paris Agreement. This will also incentivize and accelerate the uptake of CPMs.

Adjustments may be made to several of the CPMs examined in this study. The table below summarizes how existing mechanisms could be adjusted to more successfully capture CVC emissions, and what would be needed to drive or accelerate that change.

TABLE 3: ADJUSTMENTS TO EXISTING CPMS TO CAPTURE EMISSIONS FROM ALL STAGES OF THE CVC MORE COMPREHENSIVELY.

CPM	Adjustments to better apply the CPM to the CVC	What is needed to drive development?
Internal carbon price	• Apply broadly to multiple business units and the supply chain. • Apply a carbon price high enough to incentivize genuine behavior change, with a clear price increase trajectory over time.	• Agreement and drive from board level to ensure all areas of a business are incentivized. • Engagement with the supply chain to ensure buy-in and avoid sudden negative impacts.
Emissions reduction credit scheme	• Apply to whole CVC scheme or portfolio of schemes, allowing the owner or developer to trade credits across their portfolio.	• Successful examples and sharing experiences will drive familiarity and uptake.
Emissions trading system	• Include built assets in ETS to incentivize low-carbon decision-making from the design stage onwards. • Link with other global schemes.	• Adjustments to entry criteria and compliance procedures by scheme operator. • Engagement between regional and international scheme operators to facilitate linking.
Hybrid	• Apply to materials, operations, or use stages, under integrated project delivery method.	• Further assessment and engagement with industry to streamline process and avoid negative impacts on competitiveness and welfare.
Carbon tax	• Apply a challenging price, or increase an existing price appropriate to an economy's income level. • Apply to early project-making stages to maximize impact through the CVC.	• Calculate potential for implementing a carbon-neutral policy.
Command and control	• Apply performance standards, in combination with other CPMs or target levels for whole-life carbon, on projects at the planning stage.	• Further explore potential for combining with other mechanisms, while exceeding minimum expectations.

Further research on carbon pricing in the CVC

The integrated CPM proposed in this paper is just one example of how carbon pricing might be better applied to capture emissions in the CVC. The work has identified a range of aspects that require further research and evaluation. This section examines these issues. Although focused on the proposed CPM, the issues are also, in many instances, relevant to established CPMs.

PRICING CARBON IN THE FUTURE

In relation to operation and user emissions, further work is needed to understand how to price carbon in the future. For example, should it be fixed at the point of the construction project gaining planning consent, or should it change over time subject to a pricing corridor?

TECHNOLOGY CHANGE AND ITS IMPACT ON FUTURE CARBON PRICE

Any building or infrastructure asset will typically operate over many years. Significant technology improvements can be expected in that time and it would be logical to account for such efficiencies in the whole-life emissions assessment of the CPM.

However, there is much uncertainty about how quickly technology deploys and is adopted. In a CVC CPM, there would be uncertainty about who should be liable if technology change were slower than anticipated at the design change stage. For example, should it be the vehicle drivers or the scheme developer who is charged more if uptake of electric vehicles is slower than anticipated on a highway scheme?

KEY MESSAGES

- Further research is needed to evaluate the possible impacts and consequences of the proposed CPM concept for the CVC. Research topics include pricing carbon in the future, carbon accounting, jurisdictional boundaries, transaction costs, and governance and emerging markets.
- Collaborative industry engagement and leadership are needed to increase industry confidence in carbon pricing and develop and test the proposed concept.
- Other opportunities to develop a model to evaluate the impacts of applying a CPM to the CVC in a given jurisdiction include working with a specific city like London, which already has plans to implement a carbon offsetting program.
- Further work is required to understand the impacts of applying CPMs at the early project-making stages (financing, development, and design). Testing this approach on a real project would provide important evidence of the concept's feasibility, as well as increasing industry knowledge of and confidence in carbon pricing.
- A dynamic model could be developed, where all the controlling parameters and variables of the CVC are described and various scenarios are implemented to understand how best to price carbon and maximize benefits.
- Further research is needed to better understand and reduce the potentially negative social impacts of CPMs. This could include pilot studies involving representative groups from across the CVC and market sectors to understand positive and negative impacts.

A better understanding of this issue, along with supporting principles, is needed to enable CPMs to better allocate future carbon costs.

PRICING AND EMERGING MARKET CONSIDERATIONS

Further consideration must be given to ensure jurisdictions are encouraged to set prices that are both achievable and equitable as well as sufficiently challenging to the CVC to drive the required low-carbon behaviors. This is particularly pertinent to emerging markets, which are expected to see the greatest future demand for development, while also facing some of the greatest cost constraints.

CARBON ACCOUNTING

Any functioning CPM for the CVC will need to be based on a comprehensive set of rules for carbon emissions accounting. Clear requirements codified in assessment protocols and standards, together with supporting guidance, are needed. These must cover the full scope of the CVC life cycle to enable repeatable and comparable carbon emissions measurement and cost valuation.

Programs of work such as the CEN Technical Committee 350 on Sustainability of Construction Works have published standards at product, building, and framework level, and offer a basis for robust carbon accounting. However, more work needs to be done to ensure repeatability of assessment across the industry and by different practitioners. Many issues remain too undefined to support a CPM deployed at scale. Aspects that warrant further consideration include:

Data quality: Specific and generic data is available and can be used to estimate emissions. Which should be used and when, and what should be done if information is lacking or of poor quality? What data quality rules should be applied for CPM compliance and how might these change over the course of a project development process?

Carbon sequestration: How might CPMs take account of carbon sequestration? This should cover construction materials (biomass), as well as activities associated with carbon capture and storage in manufacturing processes. How should this be priced over the CVC life cycle and what incentives should the CPM provide (if any) to use the built environment as a location in which to sequester carbon?

Offsetting: How should CPMs address carbon offsetting? This could be particularly relevant to offsetting between development sites, for example, if carbon savings from implementing renewables on one site can be claimed against a scheme on another.

Scale and specificity of CPM strategies: Options exist for establishing CVC CPMs that consider discrete assets or account for multiple assets across a portfolio. Rules might be extended to account for priorities in new build or refurbishment. Could the carbon saved through a refurbishment project with short-term payback be used to seek approvals for another project?

Service and end-of-life scenarios: Carbon emission profiles for assets that reflect future service and end of life are uncertain, particularly due to the long lives expected for most buildings and civil infrastructure. Methods for how to deal with this uncertainty and ensure consistency within CPM accounting would be required.

Dealing with multifaceted functions: Buildings and infrastructure may provide multiple functions beyond those originally envisioned. For example, a hydro-electric dam may provide flood elevation as well as generate energy. The project will represent a complex set of carbon benefits and impacts. Should CPMs recognize this balance within accounting protocols or merely focus on emissions mitigation?

Industry carbon targets and decarbonization pathways, science-based targets, and asset benchmarks: The CVC is not well informed when it comes to carbon-based targets for its civil assets and buildings. Understanding low-carbon benchmark levels and future sectoral decarbonization pathways will help with positioning and deploying CPMs. With this appreciation, CPMs will also align better with NDCs.

JURISDICTIONAL BOUNDARIES

The proposed integrated CPM requires further investigation to understand how it might impact on, and integrate with, CPMs already established in the market. How the design might change to ensure best fit across neighbouring borders and jurisdictions has not been fully considered. For example, as the integrated CPM is applied there may be potential to apply opt-outs, or take bespoke approaches either on a project-by-project basis or to different asset classes. Relevant variables that affect these strategies require careful consideration, including jurisdictional priorities, welfare issues, and carbon price threshold.

TRANSACTION COSTS

If a supplier is manufacturing a product in a jurisdiction where a CPM is operating and then exports this product to another jurisdiction where a different CPM is operating, then a balance of payments must be assured to avoid double pricing carbon. In principle, only one transaction cost is needed, which will go to the scheme with the higher carbon price. However, if the supplier is operating in a jurisdiction with no CPM, then every time the product is imported into a jurisdiction with a CPM the full transaction cost of carbon would have to be paid. Such cross-jurisdictional pricing and assuring fair balance of payments is complex. It requires further research to develop different model approaches. In addition, carbon leakage is a risk where CPMs are not aligned across jurisdictions. As outlined in Article 6 of the Paris Agreement, voluntary cooperation should be encouraged to ensure mechanisms are aligned, helping countries to meet their NDCs.[80]

GOVERNANCE AND EMERGING MARKETS

The proposed CVC CPM has a regulatory and governance body to oversee it. Establishing and running such an entity would be costly and carry an administrative burden. Integrating the concept with existing planning processes would likely reduce this risk. However, further research is required to understand the feasibility of this approach, as well as adapting existing schemes such as EDGE.

INDUSTRY LEADERSHIP

Industry leaders have an important role to play in engaging with national and regional governments to:

- Oversee and provide input on the development and trial of the proposed concept in a specific locality or organization.
- Model the implications for the CVC of a CPM in a given jurisdiction. This might include working with a city like London, where plans have been set out by the Greater London Authority to implement a carbon offsetting program largely focused on retrofitting homes and non-domestic buildings.[81]
- Undertake further analysis of how CPMs could be targeted to influence behaviors in the early stages of the life cycle.
- Develop a dynamic model where all the controlling parameters and variables of the CVC can be described and various scenarios can be implemented to price carbon and maximize the benefits of selecting the construction type and method of CPM with the highest impact on emissions reductions.

UNDERSTANDING USER BEHAVIORS

Existing CPMs have tended to focus on production-based emissions. As such, there is limited research on the potential impacts of consumption-based carbon pricing on CVC behavior, including how users of buildings and infrastructure may respond. What are the associated socioeconomic impacts that may occur across different civil and building asset classes?

Understanding and reducing the potential social impacts of CPMs is complex and requires further investigation. This should be supported by pilot studies involving representative groups from across the CVC and market sectors to understand positive and negative impacts.

Appendix

Worked Example of Integrated Concept

The carbon price of the proposed integrated CPM should be responsive to global carbon markets. The proposed CPM should also be able to respond to and interact with other CPMs, without resulting in double pricing and uncompetitive outcomes for those in or outside the jurisdiction.

Below are several scenarios that could occur in relation to the integrated concept design. They also illustrate how the concept could align with wider carbon pricing markets.

BLANKET CPM: ALLOWING FOR WIDER CARBON MARKETS

A blanket approach applies a set price for carbon, for example $40; any previously paid carbon levies are deducted from the set carbon price. Table 4 illustrates how applying a blanket CPM would affect project costs.

TABLE 4: UNDER A BLANKET CPM APPROACH, ANY CARBON-RELATED CHARGES ALREADY PAID WILL BE DEDUCTED FROM THE FINAL FIGURE OWED.

Example project CPM, set price of carbon: $40/tCO$_2$e					
Project activity	**Project emission (tCO$_2$e)**	**CPM carbon price levy ($)**	**Other CPM carbon price ($)***	**Other CPM carbon price levy ($)**	**Final project CPM carbon levy ($)**
Material 1	100	4,000	10	1,000	3,000
Material 2	400	16,000	5	2,000	14,000
Material 3	600	24,000	30	18,000	6,000
Diesel	20	800	15	300	500
Electricity	5,000	200,000	20	100,000	100,000
Total	**6,120**	**244,800**		**121,300#**	**123,500+**

* Existing carbon price applied in another jurisdiction on a supplier's material
# indicates the amount CVC already paid to wider carbon pricing markets
+ indicates the amount left to pay as carbon levy by CVC

FIGURE 35: IN THIS EXAMPLE PROJECT, THE MAJORITY OF EMISSIONS DERIVE FROM ELECTRICITY.

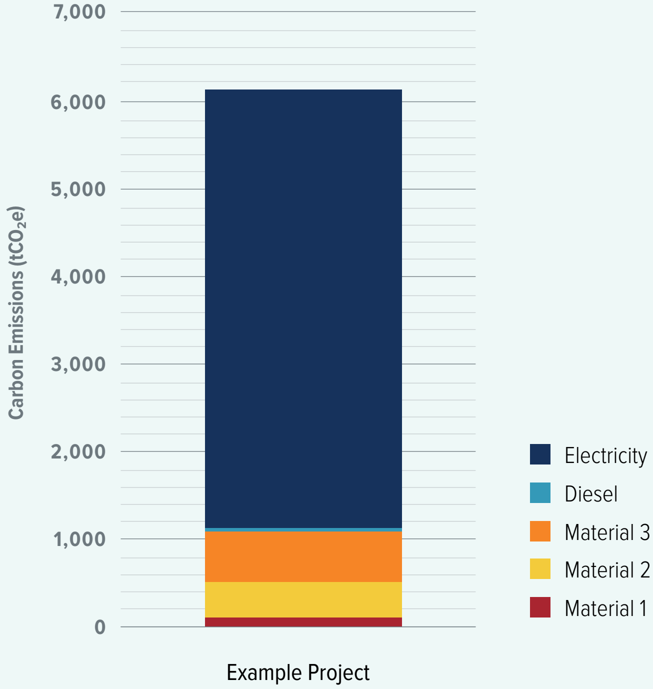


Figure 35 shows the total greenhouse-gas emissions across the CVC from products (materials), construction, operation, and use for an example project. Under the blanket CPM approach, a set carbon price would be applied to every element. In the example shown in Table 4, this would be $40 per ton of CO_2e without exemptions or a threshold.

THRESHOLD CPM: NO RECOGNITION OF WIDER CARBON PRICING MARKETS

Scenario 1: A threshold or maximum emissions level (for example, 2,000 tons) is set and a price on all remaining carbon emissions (for example, $40) is applied.

For a threshold approach, jurisdiction A sets a threshold level (in Figure 36 this has been set at 2,000 tons) and a carbon price is paid on the difference Δ between the aggregated emissions of material supply, construction, and operations, and the jurisdictional CPM threshold level.

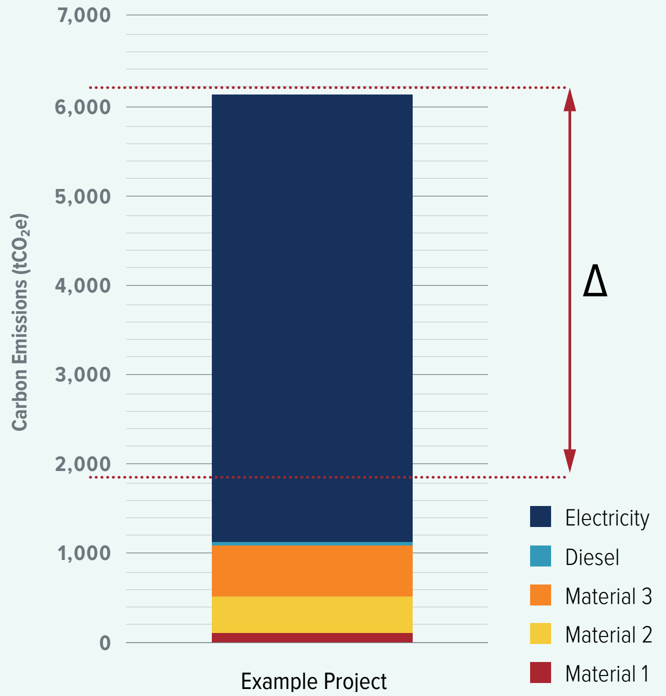
THRESHOLD CPM: ADJUSTED TO RECOGNIZE SUPPLY CHAIN ACTIVE IN WIDER CARBON PRICING MARKETS

Table 5 demonstrates how a threshold model would work if no carbon levies have previously been paid (Scenario 1). If a project importing materials from jurisdiction B or C has already applied a carbon levy, two options may arise. In the first, the CPM of jurisdiction B applies a carbon price of $20, which is lower than the price in jurisdiction A (see Table 6 for Scenario 2). In the second option (Scenario 3), a carbon price of $50 is applied by another jurisdiction (C), which is higher than the $40 applied by jurisdiction A (see Table 7).

TABLE 5: THE TABLE SHOWS THE DIFFERENT PRICES FOR PROJECT ACTIVITIES AND THE RESULTING TOTAL TO BE PAID MINUS THE THRESHOLD DEDUCTION.

Example project CPM, set price of carbon: $40/$tCO_2e$		
Project activity	Project emission (tCO_2e)	CPM carbon price levy ($)
Material 1	100	4,000
Material 2	400	16,000
Material 3	600	24,000
Diesel	20	800
Electricity	5,000	200,000
Total	**6,120**	**244,800**
Project CPM threshold (deducted from project)		**2,000 tCO_2e**
Project to pay price on (Δ)		**4,120 tCO_2e**
Project carbon price to pay		**$164,800**

FIGURE 36: THE DISTRIBUTION OF CVC EMISSIONS AND THE APPLICATION OF A THRESHOLD LEVEL THAT DISCOUNTS THE CONSIDERATION OF THESE EMISSIONS.



Scenario 2: Project CPM higher than wider markets average

TABLE 6: IMPACT OF A THRESHOLD MODEL WHERE A CARBON LEVY HAS PREVIOUSLY BEEN PAID IN JURISDICTION B, WHICH HAS A LOWER CARBON PRICE.

Example project CPM, set price of carbon: $40/tCO_2e$			
Project activity	Project emission (tCO_2e)	CVC carbon price ($)	CVC carbon price levy ($)
Material 1	100	20	2,000
Material 2	400	20	8,000
Material 3	600	20	12,000
Diesel	20	20	400
Electricity	5,000	20	100,000
Total	**6,120**		**122,400**

- **Project CPM threshold:** 2,000 tCO_2e
- **Project to pay a price on (Δ):** 4,120 tCO_2e
- **Project price to pay:** $164,800
- **CVC levy already paid:** $122,400
- **Project CPM left to pay:** $42,400 ($164,800 – $122,400)

Scenario 3: Project CPM lower than wider markets average

TABLE 7: IMPACT OF A THRESHOLD MODEL WHERE A CARBON LEVY HAS PREVIOUSLY BEEN PAID IN JURISDICTION C, WHICH HAS A HIGHER CARBON PRICE.

Example project CPM, set price of carbon: $40/tCO_2e$			
Project activity	Project emission (tCO_2e)	CVC carbon price ($)	CVC carbon price levy ($)
Material 1	100	50	5,000
Material 2	400	50	20,000
Material 3	600	50	30,000
Diesel	20	50	1,000
Electricity	5,000	50	250,000
Total	**6,120**		**306,000**

- **Project CPM threshold:** 2,000 tCO_2e
- **Project to pay a price on (Δ):** 4,120 tCO_2e
- **Project price to pay:** $164,800
- **CVC levy already paid:** $306,000
- **Project CPM left to pay:** in this case the scheme ends in credit: $141,200 ($164,800 – $306,000)

Scope of Carbon Pricing Mechanisms in Buildings and Infrastructure

The CPM could be applied to either buildings or infrastructure and their defined subsectors. Across life-cycle modules A and B, the CPM could address capital and operational carbon emissions and could, on occasion, be applied to manage user emissions.

Sector	Subsector	Capital carbon	CPM	Operational carbon	CPM	Use carbon	CPM
Domestic buildings	Housing	Construction of new housing	✓	Heating	✓	N/A	-
	Refurbishment of housing	Housing refurbishments & maintenance	✓	Cooling	✓	N/A	-
		Emissions from waste processing/treatment and final disposal from construction, maintenance, and demolition activities of housing	✓	Hot water	✓	N/A	-
				Ventilation	✓	N/A	-
				Other regulated energy (e.g. lifts)	✓	N/A	-
				Cooking	-	Gas and electric cooking (cookers only)	-
				Unregulated energy	-	Plug load electricity (i.e. all appliances)	-
Non-domestic buildings	Public buildings**	Construction of new public buildings	✓	Heating	✓	N/A	-
	Industrial**	Construction of new industrial buildings	✓	Cooling	✓	N/A	-
	Commercial**	Construction of new commercial buildings	✓	Hot water	✓	N/A	-
	Refurbishment of non-domestic buildings	Refurbishment & mainteinance of non-domestic buildings	✓	Ventilation	✓	N/A	-
		Emissions from waste processing/treatment and final disposal from construction, maintenance, and demolition activities of non-domestic buildings	✓	Lighting	✓	N/A	-
				Other regulated energy (e.g. lifts)	✓	N/A	-
				Cooking	-	Gas and electric cooking (cookers only)	-
				Unregulated energy	-	Plug load electricity (i.e. all appliances)	-

Sector	Subsector	Capital carbon	CPM	Operational carbon	CPM	Use carbon	CPM
Infrastructure	Infrastructure-Energy	Construction of power stations, and energy distribution networks	✓	Grid losses (SF_6)***	-	N/A	-
	Infrastructure-Telecommunications	Construction of communication networks, cabling, masts, etc.	✓	Energy use to power telecommunications networks, data centres, transmitters, etc.	✓	N/A	-
	Infrastructure-Water	Construction of reservoirs, pumping stations, treatments works, and distribution networks	✓	Conveyance and supply of potable water. Conveyance and treatment of waste water. Direct emissions from potable waste water treatment	✓	N/A	-
	Infrastructure-Transport	Construction of road, rail, airports, and port facilities	✓	Street and public realm lighting. Gantries, signage, signaling, etc.	✓	Vehicular emissions	✓*
	Infrastructure-Waste	Construction of waste processing, treatment, recycling, and final disposal facilities	✓	Energy used to power waste handling, processing, and treatment equipment. Transport of waste could also be included if deemed appropriate	✓	Direct emissions of final disposal e.g. incinerators and landfills	✓****
	Refurbishment infrastructure	Infrastructure refurbishment & mainteinance	✓	N/A	-	N/A	-
		Waste from any construction, maintenance of demolition activities, or infrastructure assets	✓	N/A	-	N/A	-

* Includes all direct and indirect vehicle emissions (highway, rail, boat, plane) within the jurisdictional boundary.

** For presentation purposes public, industrial, and commercial categories are used as summary headings to represent the wider building stock. Fuller non-domestic building definitions and scopes for CPM could be developed.

*** Energy grid system losses and associated emissions would be accounted for within the relevant operational and use categories for buildings and infrastructure assets. However, losses arise due to infrastructure system inefficiencies that can be more directly associated with energy infrastructure so it might be better to assign it to the energy sector. Care would have to be taken to avoid double counting.

**** Direct emissions from the use of waste infrastructure that provides end disposal solutions such as landfill, composting or incineration.

Endnotes

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5 International Energy Agency (2017), http://www.worldgbc.org/sites/default/files/UNEP%20188_GABC_en%20%28web%29.pdf

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24 Mott MacDonald (2015), https://www.mottmac.com/views/pas-2080-prepare-for-worlds-first-specification-on-carbon-management

25 Please note that there are many more delivery mechanisms and substructures therein. This list outlines some of the most frequently used models in the construction industry.

26 The choice of delivery method will also depend on project type, size, complexity, and client priorities. More integrated approaches are not always better at achieving carbon savings.

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40 LSE (2017), http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2017/12/How-to-make-carbon-taxes-more-acceptable.pdf

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44 CPLC (2018), CVC Task Team Background Paper Construction Industry Value Chain: How Companies Are Using Carbon Pricing to Address Climate Risk and Find New Opportunities

45 Ibid.

46 Financial Stability Board: Task Force on Climate-related Financial Disclosures, https://www.fsb-tcfd.org/

47 Given the small number of case studies tested, this analysis does not separate buildings and infrastructure products and materials with the highest carbon costs.

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