GLOBAL CARBON REWARD

FROM CLIMATE GRIDLOCK
TO A REGENERATIVE FINANCIAL SYSTEM

2022

POLICY WORKING PAPER

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Organisation

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Public Notice

The GCR policy continues to evolve in dialogue with key stakeholders, and later revisions of the policy will reflect these refinements. The ideas presented herein do not necessarily reflect the views of the people or organisations who are mentioned.

Policy Versions

This policy working paper describes the 2022 base-case GCR policy. Future policy versions should be referenced relative to this 2022 base-case policy. New policy versions will allow for new policy options and refinements.

Citing this Report

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https://globalcarbonreward.org/gcr-project-meetings/key-references/

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Abstract

The **global carbon reward** (GCR)[1] is a newly proposed international climate policy that aims to mobilise the global cooperation and scalable finance that are urgently needed to achieve the 1.5-2.0°C goal of the 2015 Paris Agreement. The GCR is a unique policy because it combines market and monetary approaches for establishing an explicit global price for GHG removal, and flexible global prices for GHG emission reductions and regenerative co-benefits. Three kinds of co-benefit are supported: energy reliability, community wellbeing and ecological health.

The GCR policy could have a "system changing" impact on civilisation given that it is framed by a powerful new type of price signal, called a **carbon reward**. The carbon reward will be delivered using a **carbon currency**, denoted as "XCC".[2] XCC is a currency-like instrument that will help finance climate mitigation — but it is not a carbon credit. The carbon reward has the scope to bridge the climate investment gap for 1.5°C, which is about:

- US $3-6 trillion/year[3] for cleaner energy and greenhouse gas (GHG) emission reductions, for the next few decades, plus
- US $1.3 trillion/year[4] to remove GHGs from the atmosphere, for the rest of this century.

The carbon reward will have these important features:

- it will be offered as a performance-based grant
- it will be debt-free and will not result in any direct costs for stakeholders
- it will have a predictable long-term price, and
- it will be issued with long-term service level agreements.

GCR implementation is reliant on the introduction of expanded mandates and new monetary policies for central banks. An expanded theory for understanding and correcting the market failure in carbon is provided in Appendix A in support of the GCR policy. The expanded theory identifies "carrot and stick" carbon pricing and the carbon currency as the "missing link" for maximising cooperation and providing scalable finance. This working paper presents the foundational concepts that may inspire collaborations for policy documentation, economic assessments, proof-of-concept demonstrations, currency pilots, and international advocacy.

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[1] https://globalcarbonreward.org/
[2] XCC is the proposed ISO 4217 code for the carbon currency.
[3] IRENA (2019), IEA (2021), OECD (2018) and McKinsey & Company (2022)
[4] Estimated from Luderer et al. (2018) and assuming US$100 per tCO2

“We are gridlocked in colossal global dysfunction...”

— António Guterres (77th UN General Assembly)
UN Secretary-General

Chapter 1. New Climate Policy

Finance Gap

There is an urgent need for additional climate finance — beyond existing public and private investment — to achieve the 1.5-2.0°C goal of the Paris Climate Agreement. The climate finance gap is measured in the trillions of USD, and is approximately:

- US $3-6 trillion/year for cleaner energy and emissions reductions over a few decades, plus

- US $1.3 trillion/year for removing at least 640–950 $GtCO_2$ of GHGs from the atmosphere over the rest of this century.

It appears that a global capacity to remove GHG from the atmosphere will be needed to counteract residual carbon emissions from hard-to-abate sectors, and to respond to any climate feedback-loops that happen to be stronger than forecast by the latest climate models.

Global Carbon Reward

The **global carbon reward** (GCR) is a combined market-and-monetary policy that is designed to mobilise cooperation and finance — at speed and scale. The policy is ambitious because it requires the coordinated support of governments and central banks to implement the policy's financial mechanism.

It is argued in this working paper that the GCR deserves attention because it will create a plausible pathway to the Paris goal through the innovative power of markets, combined with the scalability of central bank support.

Carrot and Stick Pricing

The carbon reward is a "carrot" that will be issued as a conditional grant to legal entities after they present evidence that they have mitigated (or will mitigate) a significant mass of greenhouse gases (GHGs).

The policy includes rules for determining the mass of **mitigated carbon**, either by:

- GHG emission **reductions**, or by

- GHG **removals** from the atmosphere and subsequent storage.

The GCR policy is organised into six reward rules, as explained in Tables 1 & 2 and in the following sections.

The carbon reward is not expected to realize the Paris goal on its own, however, and this is because the carbon reward belongs to a toolkit of carrot-and-stick policies. The carbon reward is noted as the primary financial "carrot" that complements carbon taxes and other "sticks", including cap-and-trade, regulations and similar policies.

These claims are supported by a new conceptual model for the **market failure in**

carbon, and an expanded economic theory for correcting the market failure with carrot-and-stick carbon pricing. The expanded economic theory is summarised in Appendix A, and the new conceptual model for civilisation's carbon stocks-and-flows is illustrated in Figure A5.

Assets, Not Offsets

The GCR policy will not involve or depend on the purchase of carbon offsets. Rather, the carbon reward will be fully-funded via a **public finance guarantee** that involves central banks (refer Chapter 4). Furthermore, 100% of the carbon that is mitigated and rewarded under the policy will be retired as soon as it is recorded. This will reduce the overall carbon-related risk because it will displace carbon offsetting as a revenue source, and it will reduce the potential for greenwashing via offsetting schemes that are weakly regulated and/or prone to gaming.

Cost-Effective Pricing

The optimal value of the carbon reward is determined using **cost-effectiveness analysis** (CE-analysis). CE-analysis is an economic optimisation approach that sets a price to achieve a non-financial objective. In this case, CE-analysis is used to target a specific carbon budget that corresponds to the 1.5-2.0°C goal of the Paris Agreement and with a prescribed degree of certainty (%) (see **Appendix A** for details).

The policy rationale is to use rewards to manage the **systemic risk** associated with the anthropogenic carbon budget. In fact, the entire GCR policy is structured as a **risk management policy**.

The policy is designed to circumvent the source of the systemic risk — which is identified as the societal bottlenecks created by the economic system itself (refer Appendix A). Societal bottlenecks (also called the lock-in effect) are attributed to the legacy systems that make-up the economy, including the monetary system, financial system, legal system, political system, media system, education system, etc.

Six Reward Rules

The GCR policy is framed by the six rules shown in Tables 1 & 2. These rules, when implemented together, will fund GHG mitigation and will improve societal and ecological resilience.

The first three rules are for (refer Table 1):

- (Rule 1) cleaner energy
- (Rule 2) cleaner business (incl. industrial processes, supply-chains and consumption behaviour)
- (Rule 3) carbon removal (i.e. from the ambient atmosphere).

Each entity will only be assessed using the one rule that best matches their primary activity.

Activities under Rules 1 and 2 are collectively called conventional mitigation.

These two rules are complementary from an energy management perspective, because Rule 1 addresses the supply-side of energy markets, whereas Rule 2 addresses the demand-side.

The policy's global price signal is actually structured by Rule 3, as explained in the following section. The price signal for carbon removal is used in the application of all three rules. Rules 1 & 2 require additional steps to modify the rewards for cost-effectiveness.

The GCR policy will address the social and ecological dimensions of the climate crisis by incentivising co-benefits and dis-incentivising harm. The following three types of co-benefit will be incentivised (refer Table 2):

- (Rule 4) energy reliability
- (Rule 5) community wellbeing
- (Rule 6) ecological health.

Rules 4 to 6 will be implemented with subjective point-scoring systems that will adjust the rewards higher or lower, depending on the assessed co-benefits and harms at the project level. See the section below on Support for Communities & Ecosystems for more details.

Priced for GHG Removal

CE-analysis will be used to determine an explicit reward price for GHG removal, otherwise called **carbon dioxide removal (CDR)**. A long-term reward price for CDR (see Figure 1) is used to structure the policy's financial mechanism, and so a clear and cogent method of determining the reward price is needed.

Large-scale CDR is considered by some environmental pundits to be physically and politically risky because CDR is not yet tested at scale, however IPCC reports reveal that large-scale CDR — in the range of 1 to 10 $GtCO_2e$ per year — will be needed to achieve the Paris goal. This is because residual GHG emissions are likely to be significant in the future based on likely policy scenarios. In other words, the most likely policy scenarios are going to involve an overshoot of the carbon budgets for 1.5-2.0°C.

The recommended assessment of CDR begins with an estimate of future GHG emissions based on the aggregate of legally binding pledges under the Paris Agreement — called **nationally determined contributions** (NDCs). The resulting GHG emissions forecast should then be used to estimate the average required rate of CDR over a 100-year planning horizon. This long-term rate of CDR will be **optimistically low** because it assumes the full implementation of the NDCs. This rate of CDR should then be used to define the carbon reward price and that structures the financial mechanism.

Calculating the reward price will require a price versus quantity relationship for CDR that takes into consideration changes in price as a result of improving technologies, economies of scale, and other factors. A hypothetical example of the reward price is shown in Figure 1.

The carbon reward price should be revised periodically. Price revisions may be made

every 5 years to synchronise with the NDC pledging cycle under the Paris Agreement.

Although the reward price is calibrated to the required rate of CDR, it can still be used to incentivise the decarbonisation of energy production and other economic sectors. How this may be done is explained in the section on Rewards for Conventional Mitigation for more details.

Conventional mitigation is critically important, because relying on CDR alone cannot achieve the Paris goal.

Setting Priorities

The GCR policy will not impede other climate policies or carbon markets that aim to reduce fossil fuel consumption by other means. Reducing fossil fuel consumption is still recognised as a necessary and first-order strategy for achieving net-zero by 2050-2070 for meeting the Paris goal. By setting the carbon reward price for CDR at an optimistically low level, the GCR policy will avoid a moral hazard because it will not encourage an over-reliance on CDR.

Market Response

The GCR policy is focused on enabling a global mitigation response, and so the policy will not offer direct assistance in the design of individual projects. Market actors are expected to design, develop and finance their own projects in response to the carbon reward. However, it is anticipated that the GCR policy will attract an ecosystem of service providers who will support and invest in new projects.

Rewards for Conventional Mitigation

Conventional mitigation is defined here as the decarbonisation of energy, goods, and services. A single global price for mitigated carbon cannot coordinate all economic sectors and industries. This is because the **green premium** for individual projects depends on many variables, such as: capital costs, currency exchange rates, debt financing, energy prices, revenue forecasts, maintenance costs, sovereign risk, technological progress, tax laws, etc.

Although the carbon reward will be calibrated to create a global CDR market, the GCR policy will use the same price signal to incentivise conventional mitigation. This will be achieved by modifying the reward with prescribed **carbon intensity baselines**. Individual intensity baselines will be prescribed for specific economic sectors or specific industries — so that the resulting reward is sufficient to invoke sufficient rates of decarbonisation.

The above-mentioned approach is consistent with CE-analysis. Additionality issues and counter-factual emission baselines are discussed in Chapter 3.

Methods of Rewarding

The GCR rulebook includes at least three methods for rewarding conventional GHG mitigation. These methods are:

● publicly advertising rules for prescribing **carbon intensity baselines** for specific sectors and industries

● publicly advertising **reverse auctions** and mitigation quotas for specific sectors and industries, and

● inviting **negotiations** with individual corporates and state-owned enterprises.

The above three methods will be combined with service-level agreements (SLAs) that may contain specific performance obligations. These methods present a new pathway for retiring dirty powerplants, and for leaving fossil fuels in the ground. This important topic is discussed in Chapter 3 in a section on the Energy Sector.

Support for Communities & Ecosystems

A notable feature of the GCR policy is the provision of a secondary price signal based on the adjustment of rewards. The reward adjustments will incentivise investors to optimise their projects for regeneration and resilience.

The following three rules are recommended for incentivising co-benefits (see Table 2):

● (Rule 4) improving energy reliability, such as with energy storage, load levelling, smart grids, etc

● (Rule 5) enhancing community wellbeing, such as with green jobs, food security, cleaner air, etc

● (Rule 6) protecting ecosystem health, such as with biodiversity protection, reforestation, habitat restoration, etc.

Stakeholders who participate in Rule 4 will need to be qualified as an energy expert. Stakeholders who participate in Rule 5 will be residents who live near projects, and the workers in supply chains. Finally, Rule 6 is designed to be eco-centric. Ecosystems will be represented by experienced land-carers, ecologists and scientists.

The reward adjustments will be determined through a process of stakeholder consultation that will take the form of online surveys. [5] Point-scoring systems may be developed by stakeholders. Guidelines will be provided for achieving consensus on the adopted point scoring systems.

The survey results will be analysed through a statistical process that aims to redistribute (i.e. adjust) the carbon rewards, and without artificially creating or destroying the rewards. A universal rule is that the sum of all of the reward adjustments should total to zero, and this

[5] For further information on the reward adjustment methodology, please see the GCR website or contact the GCR organization.

is to maintain the integrity of the carbon stock-take.

The adjustment of the rewards through stakeholder responses to Rules 4, 5 and 6 should result in a positive **distributional effect** across the world economy.

Support for R&D

A key benefit of the price signal for the carbon reward is that it will span a 100-year planning horizon (see Figure 1). This long-term price signal will trigger a massive wave of private R&D given the high earnings potential of climate solutions that are scalable. This R&D will lower the cost of low-carbon technologies over the long-term.

Social Justification

The GCR policy is not designed to optimise the efficiency of markets under cost versus benefit analysis (CB-analysis). This feature of the policy may be viewed as contradictory to standard economic theory and philosophy. However, the expanded economic theory in **Appendix A** explains why the GCR policy is complementary to standard policies.

The GCR policy will function as a risk management policy, and the optimisation approach is termed cost-effectiveness (CE). The social principle for justifying the approach is named **preventative insurance**. By analogy, the principle of preventative insurance may be compared with preventative healthcare, and with physical insurance, such as using a seatbelt when driving a car.

Preventative insurance against dangerous-to-catastrophic climate change is necessary because of the dynamic nature of the problem. This includes the dynamic behaviour of societal systems and Earth systems. These concepts are formalised in **Appendix A**.

The new social agreement of the GCR policy requires that central banks act as the "buyers of last resort" for the XCC. This monetary approach is scalable and commensurate with the climate problem (refer Chapter 4).

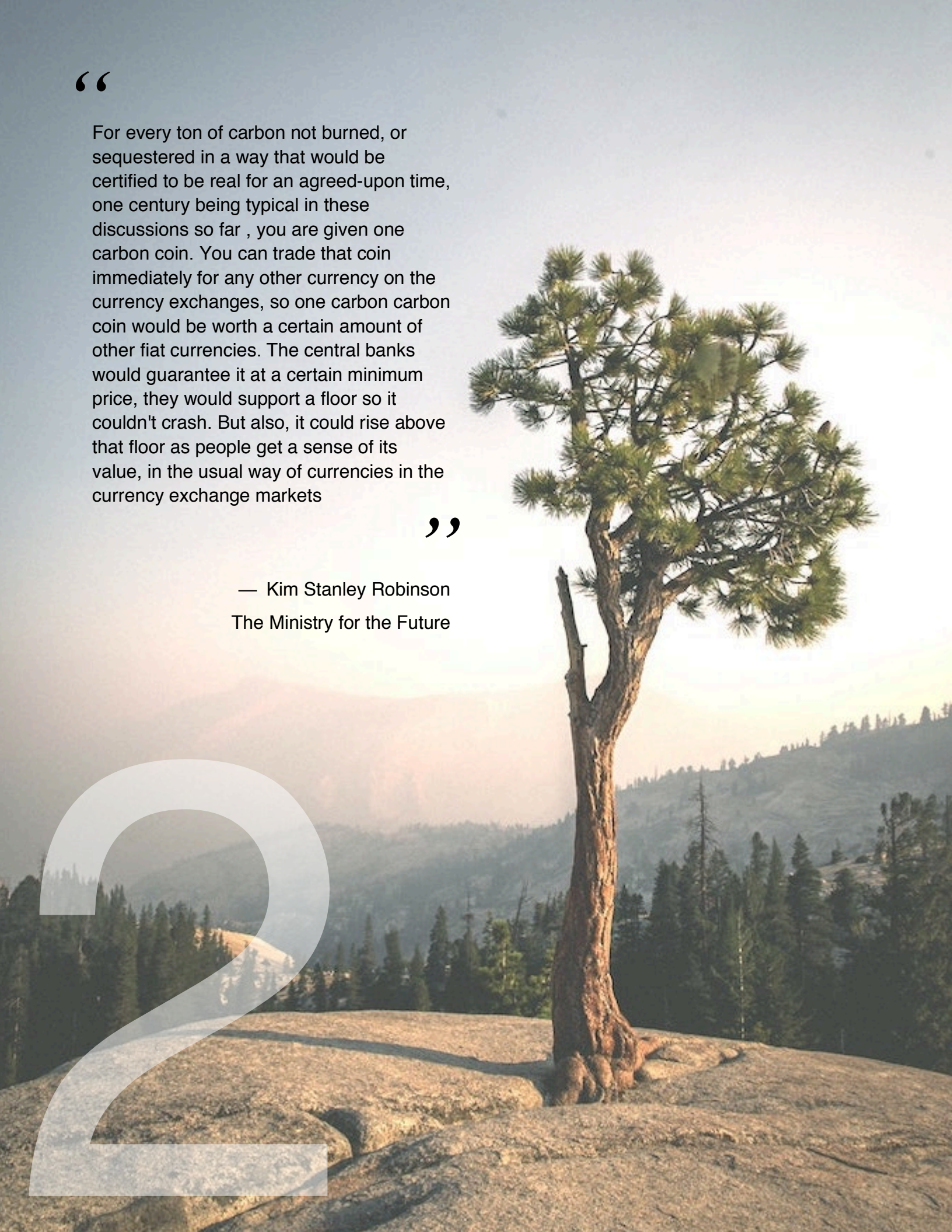
A limitation of the Paris Agreement is that it lacks an enforceable mechanism for mitigating global warming. This limitation may encourage countries to free-ride on the efforts of other countries. The GCR policy offers a potential resolution to the free-rider problem by diverting a significant portion of the mitigation cost away from stakeholders and into currency markets.

The GCR policy may also alleviate the historical inequity between the global north and the global south by creating new long-term revenue streams for the global south. This may include rewards for carbon farming in rural areas, and rewards for facilitating the exchange of proven fossil energy reserves for new clean energy infrastructure (refer Chapter 3).

Policy Jurisdiction

The GCR policy aims to serve all nations of the world. However, only the technologies and methods that are legally permissible and do not deny human rights[6], will be rewarded under the policy.

[6] Human rights as defined by local and internationally-agreed laws.



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For every ton of carbon not burned, or sequestered in a way that would be certified to be real for an agreed-upon time, one century being typical in these discussions so far , you are given one carbon coin. You can trade that coin immediately for any other currency on the currency exchanges, so one carbon carbon coin would be worth a certain amount of other fiat currencies. The central banks would guarantee it at a certain minimum price, they would support a floor so it couldn't crash. But also, it could rise above that floor as people get a sense of its value, in the usual way of currencies in the currency exchange markets

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— Kim Stanley Robinson

The Ministry for the Future

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Chapter 2. Financial Instrument

Carbon Currency (XCC)

The proposed **carbon currency** will be issued digitally and in proportion to the mass of carbon that is mitigated under the reward rules (see Rules 1 to 6 in Tables 1 & 2). The carbon currency will be an official asset and not a cryptocurrency. It will not be traded as a carbon credit, and it will never be used to offset emissions.

It is presumed that the carbon currency will be given the code "XCC" under ISO 4217 because the currency represents mitigated carbon. Analogous examples under ISO 4217 are the gold currency (XAU), silver currency (XAG), palladium currency (XPD), and platinum currency (XPT).

The XCC will be a representative currency with a unit-of-account of **1 tonne of carbon dioxide equivalent (CO_2e) mitigated for a 100-year duration**. The GCR policy allows the issuance of XCC for mitigation outcomes that are shorter than 100 years. This may occur via pro-rata time calculations relative to the 100-year standard. For example, 2 tonnes of CO_2 mitigated for 50 years may be treated as 1 tonne of CO_2 mitigated for 100 years.

Every tonne in the carbon stocktake will be associated with a service-level agreement, and for this reason the XCC ledger will track the total mass of mitigated GHGs under the policy.

XCC Supply-Demand

The XCC supply will result from:

- the periodic and perpetual issuance of XCC for mitigated GHGs.

The XCC demand will result from:

- the periodic and perpetual purchase of XCC by central banks, and
- private investor demand for the XCC.

XCC Exchange Rates

The carbon reward will be issued as XCC, but the reward itself is not expressed in XCC units. The economic value of the carbon reward is defined by exchange rates. For example: XCC/USD, XCC/EUR, or XCC/CNY. Any quote currency may be used to define the value of the carbon reward with time.

For every ton of carbon not burned, or sequestered in a way that would be certified to be real for an agreed-upon time, one century being typical in these discussions so far , you are given one carbon coin. You can trade that coin immediately for any other currency on the currency exchanges, so one carbon carbon coin would be worth a certain amount of other fiat currencies. The

central banks would guarantee it at a certain minimum price, they would support a floor so it couldn't crash. But also, it could rise above that floor as people get a sense of its value, in the usual way of currencies in the currency exchange markets

XCC Trading

The XCC will act as a store-of-value for its holders. This store-of-value function will conclude when holders swap their XCC for national currencies of their choosing. This XCC trading will be facilitated through know-your-customer accounts managed by wholesale and retail currency brokers.

The XCC will be convertible into other currencies. Analogous examples are the trading of XAU as XAU/USD, XAU/EUR or XAU/CNY currency pairs.

XCC Anti-Greenwashing

The XCC will limit greenwashing because:

- it will not act as a carbon credit for the offsetting of GHG emissions
- it will not require energy-intensive computer “mining” to maintain security.

XCC Floor Price

The XCC’s exchange rate will be partly managed so that it never falls below a guaranteed floor, called the **XCC floor price** (see Figure 1). Maintaining this floor price is the primary purpose of the public finance guarantee (refer Chapter 4).

The XCC floor price will be determined and managed relative to a basket of currencies (e.g. G20 currencies) because the GCR policy seeks to establish an international price for carbon. In this working paper, the XCC is discussed in terms of the XCC/USD pair to simplify the policy presentation and because the USD is the world’s reserve currency.

XCC Functionality

By design, the XCC is not legal tender because it will not be used to buy goods and services. In other words, it is not a medium-of-exchange. The XCC will enable these policy functions:

- it will create an explicit long-term reward price for GHG removal
- it will enable to a flexible long-term reward price for conventional GHG mitigation
- it will enable the voluntary redistribution of mitigation costs via private and public currency trading and investing
- it will enable a secondary price signal for promoting community wellbeing and ecological health
- it will invite a new ecosystem of financial and consulting services for the GCR marketplace.

XCC Assets, Not Debt

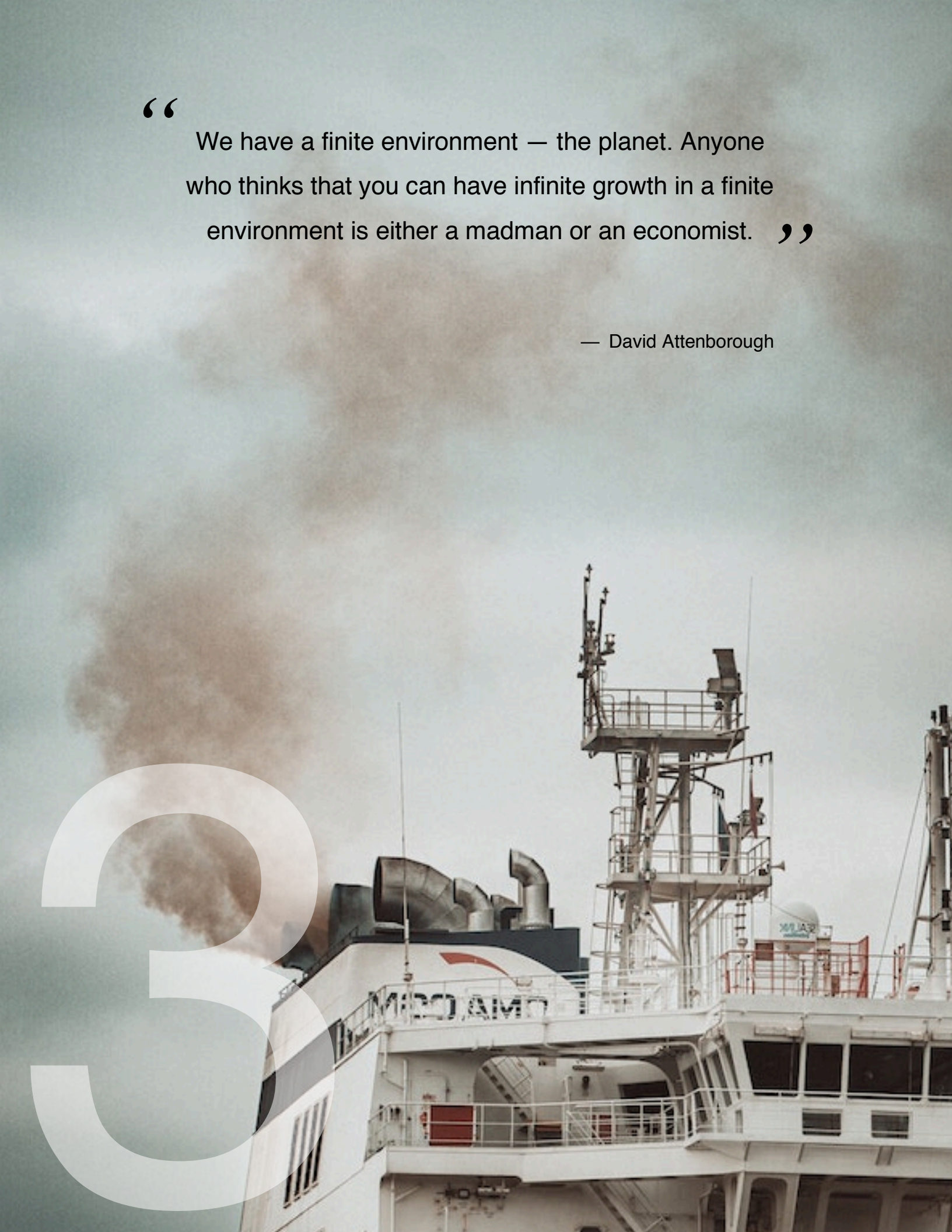
The XCC will be convertible with national currencies. This trading will occur in wholesale and retail currency markets. Financial institutions and citizens will be able to invest in the XCC.

Given that the XCC will be underwritten by a public finance guarantee (as described above and in Chapter 4) currency traders will view the XCC as a financial asset with limited-risk. The XCC's value will not correlate with stock markets, and so it will be seen as an investment option for portfolio diversification and protecting wealth. The XCC may be used as a **safe haven** investment.

From a broader economic perspective, the public finance guarantee underpinning the XCC floor price will influence the global money supply because it involves central banks expanding the base money supply (M0) with debt-free bank reserves (refer Chapters 4 & 5).

“We have a finite environment — the planet. Anyone who thinks that you can have infinite growth in a finite environment is either a madman or an economist.”

— David Attenborough



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Chapter 3. Mitigation Assessments

Carbon Exchange Standard (CES)

The rulebook and guidelines for the GCR policy are summarised in Tables 1 & 2. Implementation of the policy will require the codification of the rulebook and related standards for measurement reporting and verification (MRV). Implementation will also require training courses, accreditation systems, and certification opportunities for third-party assessors.

The above items will constitute the **carbon exchange standard** (CES) for assessing the mass of mitigated carbon at the project level.

The CES will also include methods and protocols for determining the XCC floor price with reference to a basket of fiat currencies. These methods and protocols will be framed by CE-analyses and risk management principles. A key input into the CE-analyses will the official NDCs under the Paris Agreement (refer Figure 1).

Carbon Exchange Authority (CEA)

The development of the CES and the implementation of the GCR policy will be the responsibility of a **Carbon Exchange Authority** (CEA). The CEA will be a newly created international institution that shall take responsibility for operationalising the policy. The CEA may be described as a global fund for climate mitigation because it will issue the XCC for mitigated carbon.

The CEA's operations may be divided into two major duties: (1) managing the supply of XCC, and (2) managing demand for the XCC. With regards to the XCC supply, the CEA will decide which industries, sectors and technologies should be prioritised for the reward. These decisions will be framed by risk assessments. The CEA will have considerable flexibility when applying the GCR policy across economic sectors and industries.

The CEA will send instructions to central banks to defend the XCC floor price (refer Chapter 4). These instructions might be relayed to central banks via a central hub, such as the Bank of International Settlements (BIS).

Participation & Disclosure

Participation in the GCR policy will be voluntary, and businesses will not be forced to disclose their emissions. Only businesses that wish to earn the carbon reward will need to disclose their emissions. The cost of the carbon accounting for market actors is implicitly factored into the carbon reward.

New Technologies

The CEA will prioritise the rewarding of technologies that can effectively mitigate GHG emissions. Subsequently, the policy does not offer special treatment for new or unproven technologies. Technologies will need to meet applicable laws and standards at local and national levels.

Performance Obligations

A novel and important feature of the GCR policy is that it allows the CEA to invite project owners to accept ambitious **performance obligations** in exchange for short-term and long-term reward payments. The performance obligations will require the project owners to complete specific tasks, such as (a) retiring carbon-intensive assets, (b) investing in new clean infrastructure, and (c) producing cleaner energy, goods or services according to a schedule.

These performance obligations can help deleverage **stranded assets** and avoid the construction of new fossil fuel extraction projects and power plants. They can also be used to protect vulnerable ecosystems and communities, and can be used to accelerate the decarbonisation of hard-to-abate industries that consume fossil fuels.

Additionality & Baselines

Private standard and UN compliant standards for issuing carbon credits have been criticised for not adequately addressing the problem of **additionality**. Additionality is the need to prove that the mitigation benefit would not have happened in the absence of the financial incentive.

When rewarding CDR under Rule 3 (refer Table 1), the GCR policy will assess the level of additionality using a **zero emissions baseline**. The GCR policy will also pro-rata the mitigated mass relative to a 100-year duration. Subsequently, the GCR policy will be similar to other carbon standards that incentivise CDR.

When rewarding conventional mitigation under Rules 1 & 2 (refer Table 1), the problem of additionality is more complex because the emission baselines are non-zero and can be difficult to evaluate. However, the GCR policy will be less vulnerable to additionality problems compared to existing carbon markets. There are two key reasons: (1) the GCR policy will not allow carbon offsetting, such that there is less need for accurate counter-factual emission baselines; and (2) the GCR policy will focus on projects that produce significant benefits and are thus unambiguous in terms of additionality.

Just like other carbon markets, Rules 1 & 2 will require the estimation of the **absolute mass of mitigated carbon** relative to counter-factual emission baselines. However, Rules 1 & 2 are not tied to these estimates of absolute mass when rewarding projects. Given that the policy will cater to projects that produce significant outcomes, the policy will focus on modifying the reward payments to be cost-effective.

The recommended approach for the modification of the rewards is to prescribe new baseline metrics that provide contextually useful information on the effectiveness of mitigation strategies and technologies. For example, the **carbon intensity per joule** of energy may be used as a baseline metric for energy producers. Another example is the **carbon intensity per dollar spent** or the **carbon intensity per unit of production.**

Carbon intensity metrics can be used to compute a **scaled mass of mitigated carbon** that is calibrated to yield rewards that are cost-effective for each industry. These carbon intensity relationships must be calibrated against the one global carbon reward price (refer Figure 1).

Economic Sectors

The following discussion of mitigation assessments is framed by the three reward rules and associated economic sectors (refer Table 1):

- (Rule 1) energy sector
- (Rule 2) other economic sectors
- (Rule 3) carbon removal sector.

Energy Sector

The International Energy Agency (IEA) recently published a roadmap for achieving net-zero CO_2 emissions by 2050 and for limiting global warming to 1.5°C[7]. Their roadmap states that fossil fuel exploration should end now. They also state that new coal mines and mine extensions should be stopped, and that "… *no new oil and natural gas fields are required beyond those that have already been approved for development.*"

Rule 1 of the GCR policy (see Table 1) can be used to transition the global energy system by offering the carbon reward to energy companies in exchange for a **performance obligation** that requires them to leave their fossil energy resources in the ground. These performance obligations will compel the energy company (or mining licence holder) to construct new strategic renewable energy infrastructure for long-term operation. Rule 1 can thus be used to facilitate an **exchange of energy assets**.

A highly coordinated application of the GCR policy could also be implemented to balance the new supply of clean energy with demand for that energy. This will require coordinating decarbonisation on the energy demand-side, using Rule 2 (see below), with decarbonisation of the energy supply-side, using Rule 1.

The exchange of proven fossil energy reserves for a performance obligation with

[7] IEA (2021), Net Zero by 2050, IEA, Paris

long-term revenue potential offers a major policy breakthrough by providing multiple benefits, including the protection of ecological reserves and communities, and the simultaneous provision of debt-free development finance. Two hypothetical examples are posited below.

The first hypothetical example is to offer performance obligations and carbon rewards to the holders of oil and gas extraction licenses in the Democratic Republic of the Congo. The Congolese Government is intending to auction oil and gas licenses there, threatening to damage peat swamp forests that store large amounts of soil carbon — potentially releasing billion of tonnes of CO_2 into the atmosphere. This example of applying Rule 1, would result in the exchange of the extraction licenses for sufficient carbon rewards so that the awardees can realise the profit potential of their licences. However, they must then build and operate strategic renewable energy infrastructure that can earn energy revenues and additional carbon rewards over the long-term. This approach would protect biodiversity and simultaneously provide the African nation with debt-free development finance.

A second hypothetical example, similar to the Congo example, is to use Rule 1 and a performance obligation to protect the old-growth rainforests, ecosystems, water catchments, and the Indigenous peoples in the Yasuni National Park, Ecuador. The Ecuadorian Government has previously lobbied for western nations to pay to keep their oil in the ground. An Indigenous movement is currently requesting a moratorium on new oil and mining concessions however the extraction-based corporates may be unstoppable under available laws. This application of Rule 1 would result in the exchange of the extraction licences for an up-front carbon reward payment that is sufficient to realize the earnings potential of the licenses, but with the condition of building strategic renewable energy infrastructure that would then generate long-term revenue from energy sales and carbon rewards.

Other Economic Sectors

The GCR policy will employ Rule 2 to decarbonise economic sectors that consume fossil energy and other high-carbon resources for producing goods and services. For example, the carbon reward could be offered for cleaner shipping, aviation, steel production, cement production, military, etc.

Consider the hypothetical example of offering a performance obligation to a shipping company. The obligation may be to replace the engines of an entire fleet of cargo ships — to convert the ships from bunker fuel to green hydrogen — within a decade. The price point of the carbon reward payments would be calibrated to be cost-effective, meaning that the rewards would be sufficient to convince the shipping company to accept the performance obligation.

Note that market actors who accept a performance obligation under Rule 2 will do so voluntarily.

Another example of applying Rule 2 involves rewarding households for the decarbonisation of the heating/cooling of their buildings. Households might qualify for the carbon reward by pooling their efforts via a fiscal sponsor. An example would be to pool the efforts for an entire apartment building, suburb, town, or city. Rewarding households might trigger other beneficial changes in behaviour, as a co-benefit.

Carbon Removal Sector

The GCR policy offers a major shift in climate negotiations by proposing to fund carbon dioxide removal (CDR) to the tune of US $100 trillion this century (refer Finance Gap in Chapter 1). Rule 3 in Table 1 describes how the mass of mitigated carbon will be assessed and then rewarded.

Rule 3 will establish an entirely new economic sector focused just on CDR, including engineered, natural, and hybrid methods of CDR. For example: direct air capture (DAC) with underground sequestration, reforestation, rewilding, carbon farming, and algae farming.

Scope 1, 2 & 3 Emissions

The GCR accounting rules for Scope 1, 2 and 3 emissions are explained in Table 1. The GCR rulebook is purposefully designed to encourage market participants to reduce their emissions rather than to offset them. Under the GCR rulebook, carbon offsetting is allowed but they are 100% disregarded in the carbon accounting for rewards.

Emissions associated with investments are also disregarded because investors typically have little or no control over the decisions made by other entities.

In all cases, project owners will need to account for all of their Scope 1 and 2 emissions, and the upstream component of their Scope 3 emissions.

In relation to Rules 1, 2 & 3, the following also applies:

- Under Rule 1, the accounting for cleaner energy production includes downstream Scope 3 emissions, but it disregards GHG removal from the ambient atmosphere. This is because the aim of Rule 1 is to decarbonise the energy supply.

- Under Rule 2, the carbon accounting for cleaner business operations includes GHGs removed directly from the ambient atmosphere. The aim of Rule 2 is to reduce the carbon intensity of goods and services, and to avoid penalising businesses for selling more goods and services.

- Under Rule 3, the carbon accounting for GHG removal includes downstream Scope 3 emissions. The aim of Rule 3 is to consider the full lifecycle of the technologies that are used to remove GHGs from the ambient atmosphere and to store them safely.

Service-Level Agreements

The CEA will issue carbon rewards (i.e. XCC payments) in response to periodic assessments that are based on Rules 1 to 6 (see Tables 1 & 2). To manage these assessments in a consistent manner, awardees will be required to enter into long-term **service-level agreements** (SLAs). The SLAs will be written by the CEA, and will include rules for defining carbon intensity emission baselines, avoided carbon (scaled and absolute mass), and rewards.

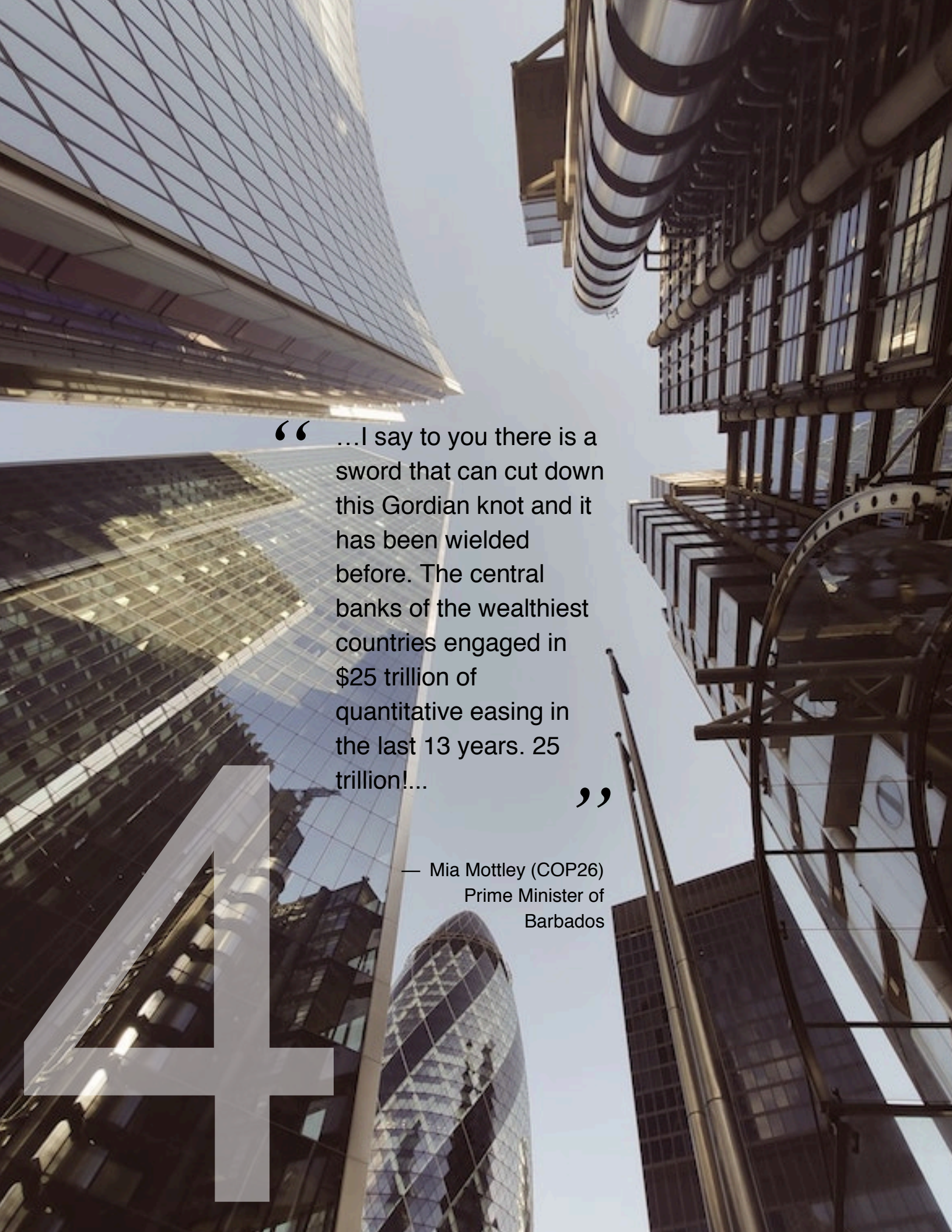
The SLA's will be designed to limit the risk of XCC overpayment and provide reliable carbon accounting. Each awardee will be associated with an individual carbon stocktake. These stocktakes will be reviewed periodically, and the reward payments will be updated to match the stocktake. **Chargebacks** will result whenever stocktakes reduce in size.

The SLAs will include conditions to define whether the reward will be paid *ex-post* or *ex-ante*. Certain mitigation technologies may be highly reliable (low-risk) such that the reward can be offered *ex-ante* of each mitigation period. However, certain mitigation technologies will be inherently risky, such that the reward can only be provided *ex-post* of each mitigation period.

The SLAs will include novation clauses for managing the handover of responsibilities to other entities, and options for dispute resolution.

Contract Defaulting

The above-mentioned SLAs will include provisions for responding to contract defaulting as a result of negligence, corruption, or *force majeure*. Defaulting is a monetary issue because some of the carbon stock and a corresponding amount of XCC should be recalled or cancelled. Recalling the excess XCC can be achieved as a chargeback. If the excess XCC is unrecoverable, then the excess XCC may be cancelled with a uniform **negative interest rate** to be charged on all private XCC holdings. Central bank holdings of XCC will not be charged the negative interest rate because these holdings are coupled to monetary liabilities.



“…I say to you there is a sword that can cut down this Gordian knot and it has been wielded before. The central banks of the wealthiest countries engaged in $25 trillion of quantitative easing in the last 13 years. 25 trillion!...”

— Mia Mottley (COP26)
Prime Minister of
Barbados

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Chapter 4. Public Finance Guarantee

Public Guarantee

A public finance guarantee is proposed as keystone feature of the GCR policy. This guarantee is needed to defend the XCC floor price and to achieve a global carbon budget that is aligned with the Paris goal. A hypothetical XCC floor price is shown in Figure 1.

It is proposed here that the public finance guarantee should be internationally coordinated by a new institution that can implement the GCR policy in its entirety. This institution was previously introduced as the Carbon Exchange Authority (CEA) (refer Chapter 3). The CEA will set the XCC floor price, and it is proposed here that the CEA should collaborate with the Bank of International Settlements (BIS) for submitting XCC buy-orders to the various central banks that are party to the public finance guarantee. These XCC trades should be coordinated to minimise the unwanted effects of the resulting monetary inflation on the world economy, as explained below.

New Central Bank Responsibility

It is recommended here that the public finance guarantee be enacted by central banks for the objective of mobilising private and public finance for helping to meet the Paris goal. This new responsibility may require that central banks be given new or expanded mandates. This new responsibility may be viewed as an extension of their responsibility to ensure financial stability. The rationale for this new responsibility is based on the expectation that weakly-mitigated or unmitigated climate damages will cause major financial instability. Of particular concern should be the long-term impacts of climate change on loss-and-damage, liability claims, stranded assets, CPI inflation, social dislocation, ecosystem breakdown, and associated risk multipliers.

The new or expanded mandates for central banks may be based on a re-interpretation of their financial stability objective however a more comprehensive justification will refer to the protection of the global commons and the planetary biosphere that nations and people depend on. These mandates may also be framed by the previously mentioned social justification, called **preventative insurance** (refer Social Justification in Chapter 1).

Carbon-QE

The carbon currency (XCC) is the proposed economic tool for mobilising private and public finance for helping to achieve the Paris goal. The market value of the XCC will be partially managed using an international monetary protocol, called **carbon quantitative easing**[5] (carbon-QE). Carbon-QE is designed to help

decarbonise the world economy, and so it is not "market neutral".

Technically speaking, the XCC floor price is a crawling-peg exchange rate system with a publicly-announced lower peg and no upper peg (see Figure 1). The CEA will be responsible for guiding the currency trading under carbon-QE. The CEA will notify participating central banks when/how to trade the XCC to defend the XCC floor price.

The XCC floor price will be calibrated to the global rate of **atmospheric GHG removal**[8] that will be needed to achieve the Paris goal based on the optimistic assumption of 100% implementation of legally-binding national pledges under the Paris Agreement (see Rule 3, Table 2).

There are two major operational objectives of carbon-QE, namely:

- carbon-QE should ensure that markets trust that the XCC spot price will equal or exceed the prescribed XCC floor price over time (refer Figure 1), and

- carbon-QE should ensure that each participating central bank is given an equitable share of XCC buy orders so that the resulting monetary inflation (if any) is as uniform as possible across all currencies involved in carbon-QE.

The second operational objective is especially important, because it proposes that the seigniorage value of newly minted national fiat (i.e. bank reserves) can be used in a coordinated fashion to fund climate mitigation, thereby harnessing the power of the world economy as a single system.

Carbon-QE will favour, indirectly, the movement of financial capital to the new profit opportunities that are created by the GCR marketplace. These opportunities will manifest where and when market actors are effective at earning carbon rewards.

The XCC floor price is expected to peak around 2060-80 because of technological improvements — and assuming that the world community is highly motivated to decarbonise (see Figure 1). During the period before the peak (i.e. phase 1) private traders will buy the XCC as an investment. During the period after the peak (i.e. phase 2) central banks may be the dominant buyers of XCC if private demand does not absorb the new supply of XCC.

To further clarify the nature of carbon-QE, consider that it will be implemented as a semi-automated protocol for the allotment of XCC buy-orders with central banks, such that:

- shifts in the exchange rates of the national currencies due to carbon-QE will be minimise (*ceteris paribus*), and

- international equity will be achieved in relation to a principle of paying for mitigation with globally uniform monetary inflation.

[8] GHG removal is often called carbon dioxide removal (CDR).

Key Benefits

The XCC floor price is inherently a social driver for mobilising wealth and rebalancing investment portfolios for effective climate action.

If carbon-QE is supported by the governments and their central banks, then:

- there will be high confidence amongst investors that the carbon reward will equal/exceed the XCC floor price, and
- the value of mitigated carbon will be referenced to national currencies.

Other key benefits of carbon-QE will include:

- transferring of private and public wealth into effective climate action
- leveraging capital flows that are supporting climate mitigation
- providing 100% funding of the carbon reward without direct costs for stakeholders
- enabling central banks to reduce carbon-related risk while retaining independence to address their existing mandates, such as price stability
- avoiding inequitable currency exchange rate shifts by sharing the monetary stimulus amongst the many central banks, and
- minimising impacts on consumers, imports/exports, and capital flows that are not directly involved in climate mitigation.

Key Concerns

In recent years the public has become aware of central bank quantitative easing (QE) and its consequences over the long-term. Two major examples are QE during the 2008-9 financial crisis, and during the COVID-19 recession. Public concerns tend to focus on the long-term risks of asset inflation, especially in the finance, insurance, and real-estate sectors: the FIRE economy.

Carbon-QE will not be like previous QE programs in terms of the long-term effects. This is because the proposed XCC purchases, under carbon-QE, will be qualitatively different because they will directly support productive businesses in the real economy, and they will not be used to support the FIRE economy.

Furthermore, carbon-QE will be gradual, orderly, and long-term. It is not a short-term stimulus package. A critical reason that carbon-QE is recommended, is that it can be used to pay for CDR to the tune of US$100 trillion this century. It is extremely unlikely that any single country could afford to cover this cost, and thus carbon-QE is a useful policy option. The cost of climate mitigation rises substantially when the cost of conventional mitigation is included.

There will be various opinions and responses to this policy working paper, especially in regards to carbon-QE and the associated monetary inflation. Primary concerns are likely to include:

- central bank mandates, and

● the required monetary expansion and resulting monetary inflation.

Secondary concerns are likely to include:

● potential for corruption

● administrative overhead related to carbon mitigation, and

● ability of renewable energy to replace fossil fuels, including the scarcity of key minerals and the need for fossil fuels to bootstrap a renewable energy economy.

These secondary concerns are more technical in nature, and would likely apply to any policy for decarbonisation.

Each of the above concerns deserve careful attention, and this working paper only aims to establish a policy framework for discussing, exploring and addressing these concerns.

Other more sophisticated concerns might relate to:

● clarifying the general role of commercial banks in the money creation process (i.e. prior to the implementation of carbon-QE)

● the impact of XCC trading on the distribution of investment portfolios, asset prices, savings, and bank lending

● the ability (or not) to use XCC in the settlement of financial transactions of various kinds

● how to provide wholesale and retail XCC trading services through existing or new financial institutions

● political resilience of the policy in a changing geopolitical landscape

● influence on debt levels, GDP per capita, and human welfare at the national level, and especially in developing countries, and

● influence on global GDP.

Addressing the above concerns will require a combination of expert consultation and quantitative economic assessments. These assessments will need to integrate economic analyses with physical boundaries related to the stocks-and-flows of energy and carbon.

The energy transition will span at least a century, and this will involve changes in capital investment patterns, savings, and consumption. Major technological advances, climate feedback-loops, and risk-multipliers could emerge that are inherently difficult to predict. Moreover, the loss and damages of climate change could produce an economic situation that is radically different to today's situation, such that economic assumptions that apply today might not apply in the future.

Given the relative complexity of the above concerns, this working paper does not attempt to answer all these concerns. Rather, a smaller set of common questions and answers is provided in the following chapter as a starting point for further policy discussions and development.

“A beautiful deleveraging balances the three options. In other words, there is a certain amount of austerity, there is a certain amount of debt restructuring, and there is a certain amount of printing of money. When done in the right mix, it isn't dramatic.”

— Ray Dalio

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Chapter 5. Questions & Answers

Will the policy create more debt?

No. The GCR policy will not create new debt (directly) because it will issue a new currency (XCC) and it will employ carbon-QE when necessary. Carbon-QE will call upon central banks to create new bank reserves (digitally and not printed) for the purchase of the XCC, but only when there is insufficient private demand for the XCC.

Central banks will treat the XCC as an asset representing service-level agreements (SLAs). Regular bank deposits are backed by interest bearing loans. Thus, the new bank reserves will be created **debt-free** before circulating. The new bank reserves will first appear in the reserve accounts of depository institutions who are acting as financial intermediaries for the XCC, or they may appear in accounts held at central banks.

Will the policy cause other prices to rise?

The policy will only cause the price of some goods and services to rise, but it will also cause a slowing of CPI inflation due to global warming. More specifically, the prices of goods and services that are needed to mitigate GHG emissions are likely to rise with the additional purchasing power associated with the XCC.

The consumer price index (CPI) provides a measure of general price changes and inflation. A long-term rise in CPI is inevitable because of global warming, but CPI is impacted by countless factors (e.g. covid19 lock-downs, deficit spending, and sanctions), and so future CPI changes are highly uncertain.

Climate change and associated extreme weather are impacting the world economy by disrupting food production, supply-chains, and productivity. Climate change is causing food insecurity and even starvation in some countries. Swiss Re estimates that 7-14% of global GDP will be lost at 2.6°C of warming. Extreme weather is becoming more frequent, and weather disasters in the U.S. have cost over $2 trillion since 1980.

The GCR policy cannot stop general CPI from rising, but it can slow its rise by targeting the Paris goal. According to “standard theory” there is an optimal level of climate mitigation based on cost-benefit analysis, but the utility of this approach is questionable because uncertainties in economic forecasting and the **carbon lock-in effect**. The GCR is based on a revised conceptual model for understanding and correcting the market failure in carbon (see Appendix A).

Will the policy cause monetary inflation?

Possibly, over the long-term. First, consider that changes in the XCC supply cannot cause monetary inflation. This is because the XCC is not legal tender. Monetary inflation, if any is created, it will be caused by changes in the base money supply (M0).

Second, consider that the supply of XCC will increase in proportion to the cumulative mass of carbon that is rewarded, and it will decrease by the amount of XCC that is purchased by central banks. It is the second process that is linked to monetary inflation. This is because the second process will employ carbon-QE, which is a protocol for central banks to guarantee the XCC floor price (see Figure 1).

Carbon-QE will contribute to monetary inflation because central banks will create new bank reserves to buy the XCC. The resulting monetary inflation will be **partly neutralised** because it will be spread globally and thinly to have the least impact on currency exchange rates.

The neutralisation of monetary inflation will be managed with an algorithm that minimises currency exchange rate shifts when other economic factors are assumed constant (*ceteris paribus*). In other words, the operational goal of carbon-QE is to devalue all national currencies at the same rate (*ceteris paribus*) so that national economies are working together to support the XCC floor price.

The explicit purpose of the XCC floor price is to ensure that the global mitigation rate is sufficient to achieve net-zero and the Paris goal. The XCC floor price has the implicit objective of attracting private demand for the XCC, thereby channelling the mitigation cost into the private sector as much as possible.

Consider that in Phase 1 there will be private demand for XCC because it is **appreciating** (see Figure 1). Monetary expansion under carbon-QE will be minimal during this phase. In Phase 2, the private sector may be a major holder of XCC, but central banks will be the "buyers of last resort" in response to the planned XCC **depreciation**. For this reason, monetary inflation is most likely to occur in Phase 2.

The two phases of carbon-QE will have the effect of **rebalancing investment portfolios** and de-leveraging the carbon-related risk — but without reckless money printing or uncontrolled monetary inflation. The proposed monetary inflation is recommended here as a primary means of deleveraging the climate crisis. Its negative consequences may be counteracted with a mix of other inflationary and deflationary policies that are available to governments and central banks.

Will the policy fund climate adaptation?

Yes, but only as a co-benefit. The GCR policy will only fund adaptation measures that qualify as the co-benefits of GHG

mitigation projects. One possible example is the provision of food security with carbon farming and agroforestry that can bio-sequester carbon. Another example is the construction of affordable housing using materials that sequester carbon.

Will the policy fund climate geoengineering?

Yes and no. The GCR policy will fund carbon dioxide removal (CDR) which is sometimes described as geoengineering. But the policy does not attempt to measure or fund solar radiation management (SRM)[9]. The policy excludes SRM from its rules and protocols because SRM is based on different physical principles to CDR. Moreover, SRM poses unique benefits and risks, and for this reason SRM, if implemented, will require a different policy approach.

Will the policy influence ESG reporting?

Yes. ESG reporting is the disclosure of environmental, social and governance outcomes by corporates. The GCR policy will influence ESG reporting by focusing attention on (a) the carbon intensity of outgoing cashflow and products, and the carbon intensity of energy, as two key measures of decarbonisation; (b) past and future carbon reward earnings by corporates; and (c) point-scores by stakeholders for assessing co-benefits and harms of specific projects and technologies.

Moreover, ESG reporting is not philosophically valid if the world economy is unsustainable. The GCR policy offers a new way to standardise ESG reporting, and to present ESG reporting for guiding the world economy towards real net-zero and a more sustainable future.

Will the policy improve ESG investing?

Yes. The GCR policy will leverage green investing, first by helping to quantify the decarbonisation rates of state-owned enterprises, corporates, businesses, and projects. Second, it has scope to establish correlations between corporate/investment profitability, and actual decarbonisation rates and improved sustainability based on XCC earnings.

[9] Humanity is already undertaking unintentional SRM because it is a side-effect of aerosol pollution. The cooling effect is called “global dimming”.

TABLES

Table 1. GCR reward rules for incentivising mitigation.

Rule	Mitigation Rulebook
1	**Cleaner Energy:** rewards will be selectively offered for retiring fossil reserves, for developing strategic energy infrastructure, and for reducing the carbon intensity of grid electricity and energy commodities. The policy allows for the use of different incentive approaches, including direct negotiations[(a)], reverse auctions, and price signals based on carbon intensity baselines[(b)] for energy supplies. For example, a reward could be offered for not extracting oil from a proven reserve. However, a major portion of the reward must be used to build cleaner energy infrastructure — thus resulting in an asset exchange. The carbon reward can be used to protect vulnerable ecosystems and communities (e.g. Congo Basin peatlands, Yasuni National Park in Ecuador). The performance obligations will be written into service level agreements (SLAs) along with standards for MRV and accounting. The computed metric under Rule 1 will be a scaled GHG mass[(c)]. Rule 1 accounting will address (Scope 1) direct emissions; (Scope 2) emissions in energy; and (Scope 3) upstream/downstream emissions. However, investments, GHG offsetting, and GHG removals will be disregarded. Removals are disregarded to encourage the decarbonisation of energy products.
2	**Cleaner Business:** rewards will be selectively offered for the decarbonisation of organisations where/when conventional policies are inadequate. This includes rewarding the decarbonisation of hard-to-abate industries (e.g. steel production, shipping, aviation), rewarding businesses (e.g. carbon farming, electrification), and rewarding households (e.g. heating/cooling, dietary). The policy allows for the use of different incentive approaches, including direct negotiations[(a)], reverse auctions, and price signals based on carbon intensity baselines[(b)]. Organisations will be offered an SLA with a specific carbon intensity baseline and standards for MRV and accounting. The computed metric under Rule 2 will be a scaled GHG mass[(c)]. Rule 2 accounts for (Scope 1) direct emissions; (Scope 2) emissions in energy; and (Scope 3) upstream emissions but not downstream. GHG removals are included in the accounting, however investments and GHG offsetting will be disregarded.
3	**Carbon Removal:** rewards will be offered for the net GHG mass removed from the ambient atmosphere and stored on a pro-rata basis relative to a 100-year period. A zero baseline is applied, and standards for MRV and carbon accounting are provided in SLAs. Rule 3 accounts for Scope 1, 2 and 3 emissions (upstream and downstream), but investments and offsetting are disregarded. Rule 3 only applies to organisations that specialise in GHG removal. Rule 3, when combined with the XCC market, will establish an explicit global price for carbon removal.

Table 2. GCR adjustment rules for incentivising co-benefits.

Rule	Co-Benefit Rulebook
4	**Energy Reliability:** a reward adjustment is offered for energy reliability. Stakeholder groups, comprised of energy and industry experts, will define the criteria for evaluating and scoring energy projects.
5	**Community Wellbeing:** a reward adjustment is offered for community wellbeing. Stakeholder groups, comprised of residents, will define the criteria for evaluating and scoring low-carbon projects and businesses.
6	**Ecological Health:** a reward adjustment is offered for ecosystem protection and restoration. Stakeholder groups, comprised of scientists and traditional land stewards, will define the criteria for evaluating and scoring low-carbon projects and businesses. Rule 6 is eco-centric, whereas Rules 4 & 5 are anthropocentric.

Footnote: Rules 4, 5 and 6 will produce a secondary price signal for promoting co-benefits.

Footnotes for Table 1
(a) The term “negotiate” refers to an ability to define and provide cost-effective rewards for specific organisations.
(b) The term “carbon intensity baseline” is a metric that records the mass of GHGs per unit of outgoing cashflow or specific goods.
(c) The scaled GHG mass is “scaled” because it is calculated from a carbon intensity baseline that has been scaled to be cost-effective. The carbon intensity baseline sets the “goal posts” for quantifying the scaled GHG mass and the carbon reward payment.

FIGURES

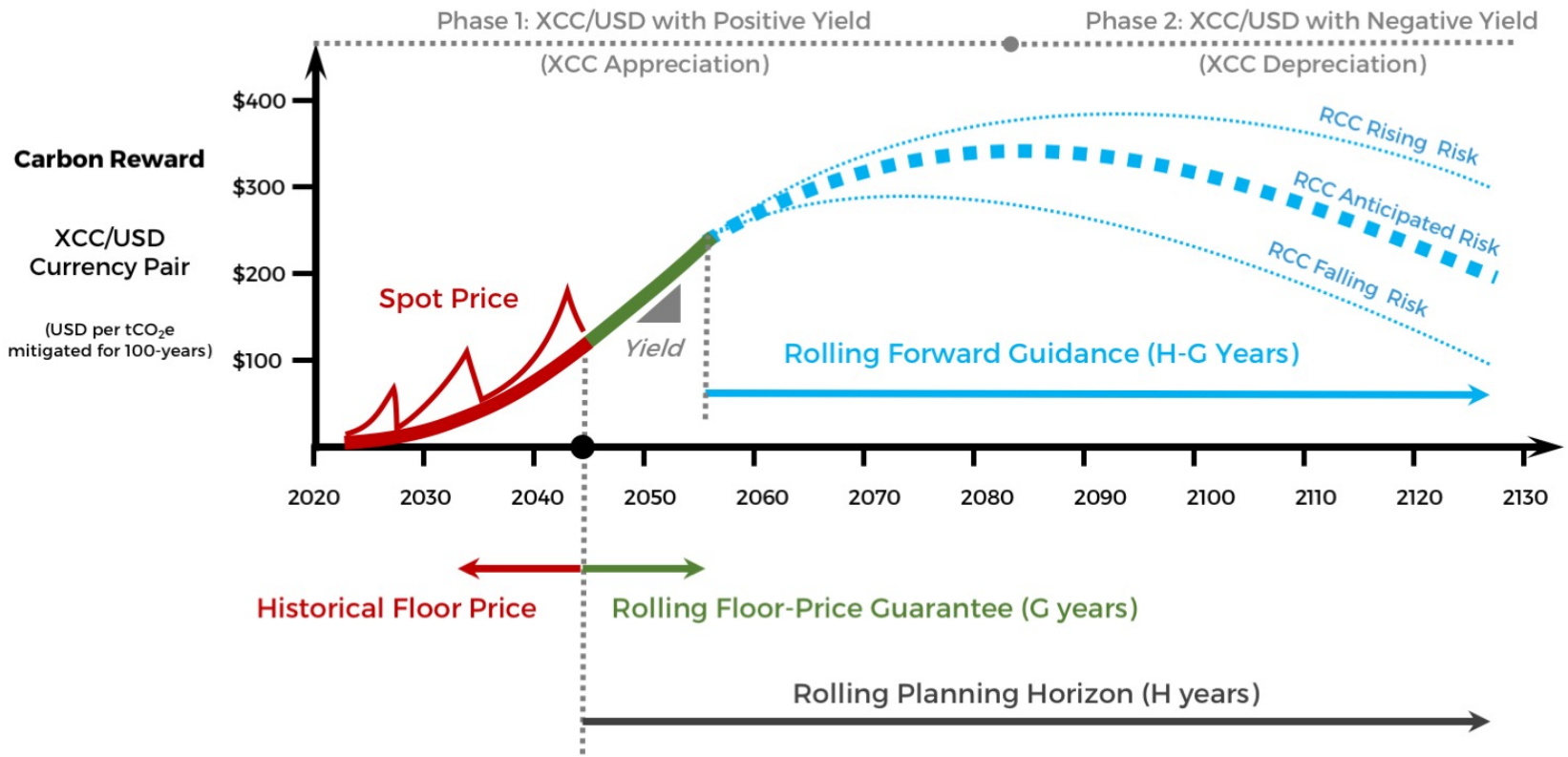

Figure 1. A global carbon reward (GCR) chart in the year 2045. In this hypothetical example, the value of the carbon reward is denoted by the XCC/USD exchange rate pair. The thick lines denote the XCC floor price. The carbon reward (XCC/USD) is anticipated to peak after mid-century due to improving technologies, and subsequently the reward has two phases: (Phase 1) positive XCC/USD yield, and (Phase 2) negative or near-zero XCC/USD yield. The recommended planning horizon (H) is a rolling 100-year period to provide civilization with sufficient forewarning of Earth system changes. The recommended duration of the price guarantee (G) is at least 10 years to attract long-term investors to the GCR market.

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Most policy references can be downloaded here:

https://globalcarbonreward.org/gcr-project-meetings/key-references/

“To test reality we must see it on the tight rope. When the verities become acrobats, we can judge them.”

— Oscar Wilde

APPENDIX A. EXPANDED ECONOMIC THEORY

A1. Revised Conceptual Model for the Market Failure

A revised conceptual model for the market failure in carbon is hypothesised by Delton Chen to explain and support the GCR policy. By revising the conceptual model for the market failure, the entire climate crisis is redefined in terms of the perceived problem and its resolution. A unique feature of the revised conceptual model is that it includes two externalities, and not just the negative externality that is explained by the "standard theory". The two externalities associate with two economic systems that comprise the revised conceptual model, as described in Table A1.

The two economic systems are coupled by the exchange rate of the proposed **carbon currency**, as illustrated in Figure 1. "XCC" is the assumed ISO 4217 code for the carbon currency. The value of XCC may be expressed relative to any national currency, but the hypothetical example in Figure 1 uses XCC/USD for convenience. The roles that the two economic systems play in the market failure, in terms of externalities, are summarised in Table A1. The first externality is the **social cost of carbon** (SCC), which is a measure of the negative externality linked to manmade GHG emissions. The second is the **risk cost of carbon** (RCC), which is a measure of a new positive externality linked to GHG mitigation.

The RCC is "invisible" to economists when relying on the theory of Arthur C. Pigou because the RCC is a measure of a systemic risk created by the mainstream economic system. Pigou did not consider that the economic system itself could contribute to a market failure as he limited his attention to the behaviour of producers and consumers. Pigou developed his theory over 100 years ago, well before global-scale market failures existed, and he did not consider the possibility that the economic system could have structural limitations. The structural limitation of the mainstream economic system is termed the **carbon lock-in effect**. The social context of the carbon lock-in effect is that it is created by the dominant **societal systems**, including fiat monetary system and financial system. The effect is made worse by an evolving dependency on carbon-intensive **engineered systems**.

The revised conceptual model proposes that a parallel economy is needed to circumvent the carbon lock-in effect that emanates from the mainstream economy. XCC is the recommended tool for circumventing the effect. This tool requires a central bank guarantee for it to be effective (Figure 1). The parallel economy will create a global marketplace for carbon rewards paid in XCC, and it can be classified as a **global public good** because it will limit the impacts of climate change for all people. The global public good is the protection of common-pool resources and the global commons from climate change, and associated impacts.

Table A1. The revised conceptual model for the market failure in carbon is based on two economic systems with complementary externalities: the SCC and RCC.

I. Mainstream Economy (Fiat Currencies)	II. Parallel Economy (Carbon Currency)
● The **negative externality** is the economic damage caused by carbon emissions. The marginal cost is quantified as the **social cost of carbon** (SCC) and it is expressed in units of *USD per tonne of CO_2e emitted in a given year*. ● The SCC is a measure of the inefficiency of the market economy, but it is insufficient for describing the market failure because the SCC overlooks the root cause of the **carbon lock-in effect**. ● The oversight is that societal systems of the mainstream economy are resistant to carbon taxes and decarbonisation, and this resistance is attributed to existing societal systems and networks (e.g. political, monetary, financial, legal) that ultimately structure the mainstream economy. Resistance to decarbonisation is further attributed to engineered systems that are specialised for using fossil fuels, and have co-evolved with societal systems. ● The **carbon lock-in effect** is the product of a complex web of inter-dependencies. Furthermore, the mainstream economy is unable to respond quickly to non-linear feedbacks in the climate system due to the carbon lock-in effect. For this reason, carbon lock-in poses a **systemic risk** to civilisation as a whole.	● The **positive externality** is the capacity to overcome the carbon lock-in effect, which is considered a systemic risk. By definition the positive externality is a global public good, because it will provide a safer climate. A safer climate can be enjoyed by all people. The benefits are non-rivalrous and non-excludable. The costs of mitigation are not carried by stakeholders. ● The main technical objective of overcoming the carbon lock-in effect is to achieve a specific **carbon budget** ($GtCO_2e$) with **certainty** (%). The marginal cost of the additional mitigation capacity is quantified as the **risk cost of carbon** (RCC). The RCC has the units *USD per tonne of CO_2e mitigated for a 100-year duration* (see Figure 1). ● A parallel economy is created when a new market instrument is created, called a **carbon currency** (XCC). The XCC is needed to internalise the RCC. ● The XCC and the parallel economy are established with new **monetary policies** and not with fiscal policies.

A2. Two-Objective Economic Optimisation

The expanded economic theory for the market failure in carbon is based on the revised conceptual model of the previous section (refer Table A1), and the presumption that the market failure in carbon is a special case because of carbon's unique physical and chemical properties. The expanded economic theory states that two optimisations are needed to define two explicit prices on carbon for correcting the market failure in carbon. The two externalities are described in summary in Table A1, and the two-objective optimisation is described in summary in Table A2 .

The expanded economic theory includes an expanded model for **time discounting**, given that a second type of time discounting is introduced. Consider that there is a long-standing debate over the ideal **social discount rate** in climate change economics. The dilemma of choosing a high or a low social discount rate is resolved here by classifying this dilemma as a **false dichotomy**. A potential resolution is provided with the introduction of a second (complementary) time discounting method for addressing the positive externality.

The time discounting dilemma is resolved in two steps. The first step is to manage the first economic optimisation with **cost-benefit analysis** (CB-analysis) and a politically feasible social discount rate — as an input parameter to the CB-analysis. The first step is to compute the SCC, which defines the ideal carbon tax. The purpose of applying the ideal carbon tax is to drive a more **efficient allocation** of goods and services in the mainstream economy.

The second step is to manage the second optimisation with **cost-effectiveness analysis** (CE-analysis) and a systemically useful planning horizon (H). The second optimisation is defined by a physical objective related to the carbon budget. The second step is to compute the RCC, which defines the ideal carbon reward. The purpose of applying the ideal carbon reward is to provide sufficient mitigation to ensure a safe carbon budget (e.g. to be Paris compliant). The rolling planning horizon (H) needs to be long enough to communicate the price signal and the climate change trendline so that civilisation has forewarning so that it can develop new technologies and re-organise to avoid dangerous climate change (see Table A2).

The two time-discounting methods are complementary and consistent with the two-objective optimisation. The rolling planning horizon (H) is based on a systemic time-model that is defined by duration and not by compounding rates. The social discount rate is an anthropocentric time-model that is defined by compounding rates and not by duration. The two-objective optimisation creates a **Pareto frontier**. Moving to the Pareto frontier represents the ideal economic pathway, and it is named "optimal growth". This growth pattern may require a trade-off, resulting in some lost efficiency for greater effectiveness (or vice versa). The expanded economic theory is further supported by the carbon pricing matrix (see Section A3) and the stock-and-flow diagram for carbon and energy (see Section A4).

Table A2. The expanded economic theory for the market failure in carbon is based on two economic systems and a two-objective optimisation.

I. Mainstream Economy (Fiat Currencies)	II. Parallel Economy (Carbon Currency)
● The **carbon tax** on emitted carbon is employed to improve the allocative efficiency of the mainstream economy. This process may be is described as "internalising" the SCC into the mainstream economy. ● The SCC is determined using **cost-benefit** analysis (CB-analysis) and social time discounting. ● A **social discount rate** is needed for the calculation of the SCC. In the revised economic theory, the ideal social discount rate is simply the rate that is politically feasible. This approach resolves the debate over whether a high or low discount rate is the ideal rate.	● The **carbon reward** for mitigated carbon is employed to achieve "carbon safety". This process may be described as "internalising" the RCC into the parallel economy. ● The RCC is determined using **cost-effectiveness** (CE) analysis and a **planning horizon** (H) that is sufficiently long to establish a price signal that is effective at stabilising the climate. ● The RCC defines the minimum carbon reward, or XCC floor price. The XCC floor price should be announced for a H of about 100 years so that civilisation can anticipate the need for new technologies and re-organisation. The rolling planning horizon (H) may be divided into a period of guaranteed prices (G) followed by forward guidance on prices (H-G) (see Figure 1). ● The parallel economy should overcome the carbon lock-in effect by (a) circumventing the societal systems of the mainstream economy, (b) helping to decarbonise the mainstream economy, and (c) removing GHGs from the ambient atmosphere to counteract residual emissions and draw-down GHGs.

A3. Carbon Pricing Matrix

The major carbon pricing options, including the carbon tax, are compared in a relational diagram, called the **carbon pricing matrix** (see Figure A1). The carbon pricing matrix is comprised of four policies in 2×2 symmetry. It defines a policy toolkit, called carrot-and-stick carbon pricing. The matrix is framed by two major options for the store-of-value of the tools (i.e. two rows), and two major options for the unit-of-account of the tools (i.e. two columns).

Carrot-and-stick carbon pricing has inherent symmetry however this symmetry involves the carbon reward policy and its currency-like instrument, called a carbon currency (XCC). The two policies in the left column of the 2×2 matrix (i.e. the carbon tax and the carbon subsidy) are explained by **Arthur Pigou's** theory for correcting externalities. The two policies in the right column of the matrix (i.e. the cap-and-trade and the carbon reward) are explained by the **Coase theorem** for reaching a **Pareto optimum**. The Coase theorem explains the utility of allowing market actors to trade an instrument with low transaction costs for the purpose of correcting a negative externality and achieving a Pareto optimum. The current application of the **Coase theorem** is novel because it is applied to the internalisation of a positive externality, denoted as the risk cost of carbon (RCC).

The carbon reward policy might also be called a mitigate-and-trade policy to be consistent with the naming convention for the cap-and-trade policy (see Figure A1). Figure A2 compares the 2×2 matrix with carbon offsetting and voluntary carbon pricing that exist outside the 2×2 matrix. Carbon credits are neither carrots nor sticks because offsetting is mainly for lowering the cost of mitigation in compliance markets. Carbon credit markets are also useful for meeting private demand for voluntary offsetting. Figures A1 & A2 do not show non-market policies, such as NDCs, laws, regulations, fiscal programs, etc.; and they do not show private initiatives, such as green investing, climate bonds, etc. However, the matrix does not ignore these policies or initiatives because they may also be classified as either carrots or sticks, and can be factored into probability distributions for achieving any particular carbon budget.

The cost-sharing model of the carbon reward (refer Figures 1 & A1) transcends the traditional concept of Coaseian bargaining because it links to a new stock-and-flow model for managing carbon at the global level (refer Figure A3). The new model posits that central banks should buy the XCC when necessary using new bank reserves, thereby expanding the base money supply (M0). Their XCC purchases will ensure that the carbon reward is high enough to achieve a target rate of mitigation. The resulting monetary inflation is presented as a means of taming demand for goods and services when technological innovation and energy efficiency improvements are not keeping pace with the remaining carbon budget. The new cost-sharing model is explained in Section A4 in terms of a system diagram and a modified Kaya identify formula for "real net-zero". The resulting monetary inflation provides an alternative to de-growth. De-growth as a policy option could be too divisive and too simplistic for managing the world economy, although it does remain an option.

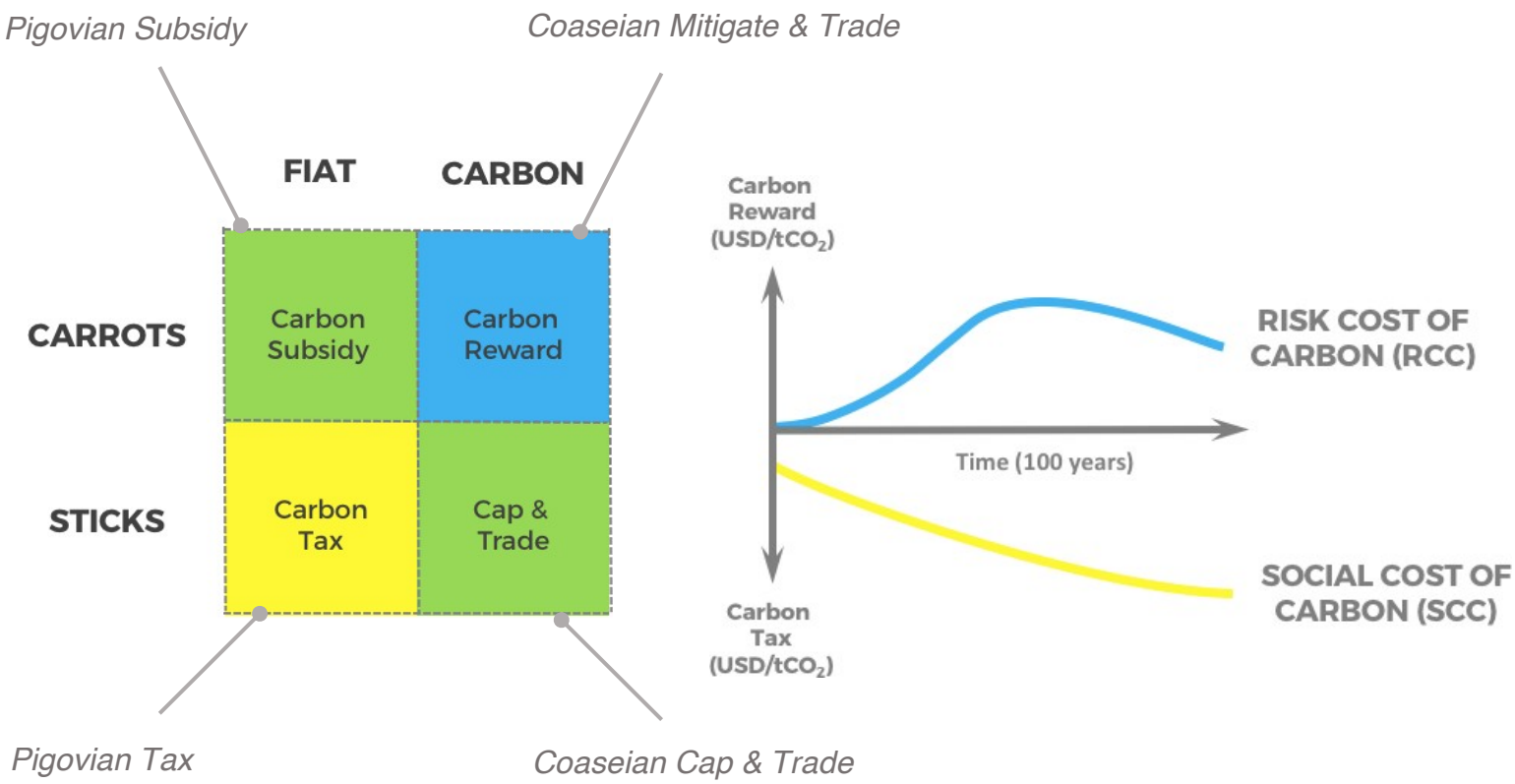

Figure A1. The carbon pricing matrix (left) is a relational diagram for understanding carrot-and-stick carbon pricing. It delineates two options for the store-of-value (i.e. the two rows) and two options for the unit-of-account (i.e. the two columns). The 2×2 matrix completes the symmetry in carbon pricing. The matrix refers to two major externalities (right). The second externality being a “missing” positive externality of the market failure in carbon, termed the risk cost of carbon (RCC).

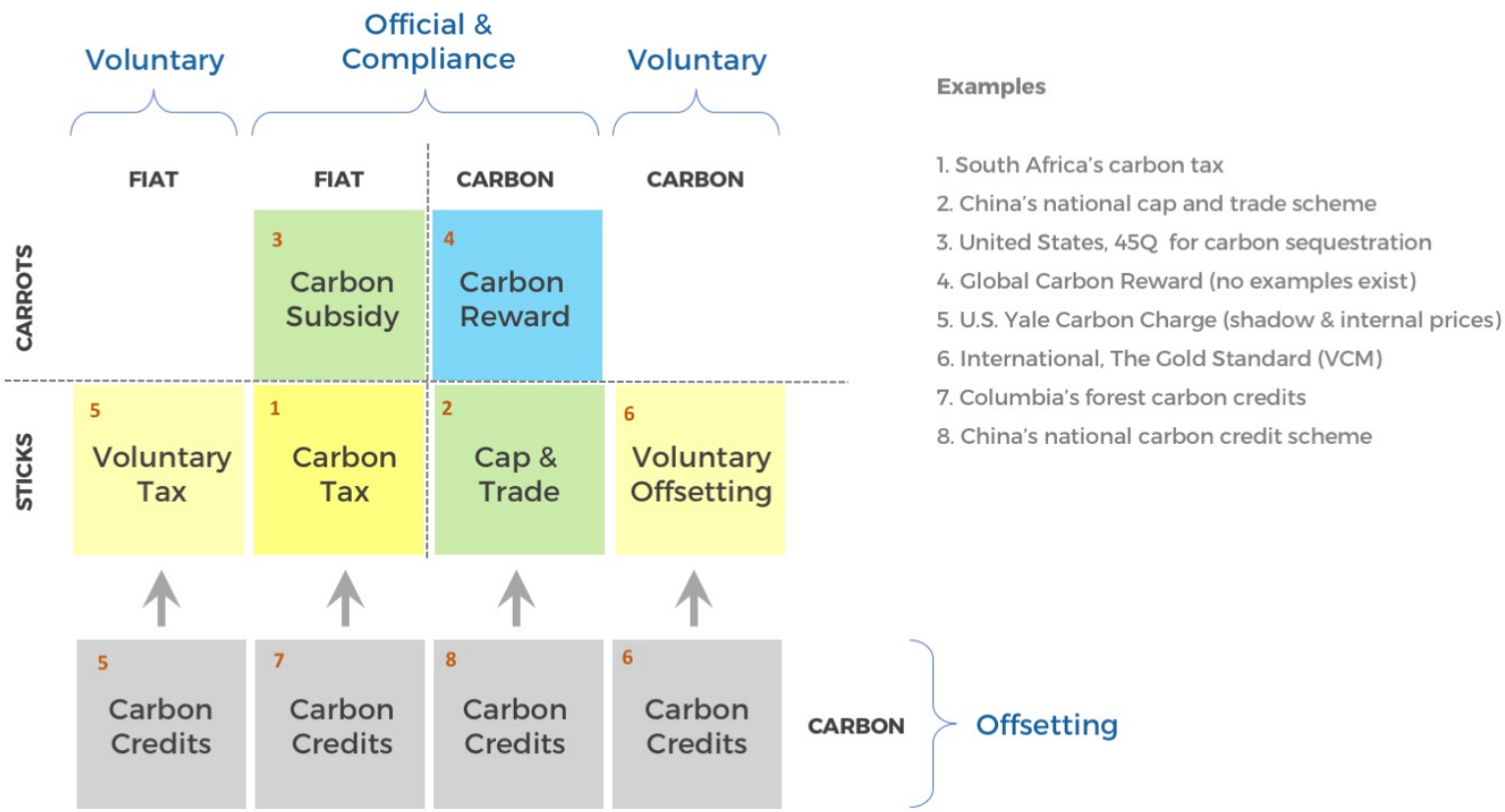

Figure A2. The carbon pricing matrix is a relational diagram for contextualising the various official and voluntary options for carrot-and-stick carbon pricing.

A4. Stock-and-Flow Model for "Real Net-Zero"

The revised conceptual model and the expanded economic theory for the market failure in carbon (refer Sections A1-A3) are supported here with a stock-and-flow diagram for civilisation (see Figure A3). This stock-and-flow diagram describes a scenario in which the carbon reward policy is fully implemented. Figure A3 is important from the perspective that it might offer a significantly better alternative to de-growth when green-growth is unable to adhere to a safe carbon budget in the face of rising consumption and GDP growth.

First, consider that the mainstream economy is structured by fiat currencies, and that the parallel economy is structured by the carbon currency (XCC) (see Figure A3). Consider that net emissions (F_{net}) will equal the manmade GHG source (F_1) from the mainstream economy, minus the manmade GHG sink (F_2) into the parallel economy. When the carbon reward policy is implemented the magnitude of F_2 will be the result of markets responding to the advertised carbon reward (refer Figures 1 & A3) and Rule 3 (refer Table 1). An important presumption is that the carbon reward will reallocate resources to create a large enough negative feedback on F_1 and a large enough positive feedback on F_2, to achieve F_{net} equals zero. The balancing of F_1 with F_2 is called "real net-zero" in this working paper.

Consider that the manmade GHG source (F_1) may be analysed with the Kaya identity (see Table A3). The notion of a parallel economy is critical at this point, because the addition of F_2 to the Kaya identity does not modify the factors in the Kaya identity, but rather it involves the addition of a second system to the original system that is being described by the Kaya identity. The addition of F_2 with F_1 represents a decoupling from the original Kaya identity, and this de-coupling is justified on the basis that the parallel economy will not produce conventional goods and services. The parallel economy is specialised for providing GHG removal services (i.e. F_2) and conventional GHG mitigation.

Careful examination of Figure A3 reveals that it does not show the emissions reductions that result from Rule 1 (i.e. for decarbonising energy supplies) or Rule 2 (i.e. for decarbonising consumption) and this is for convenience because these reductions are difficult to illustrate. The relevant changes in carbon stocks-and-flows are explained by the formulas in Table A3. Rules 1 and 2 are used to create the aggregate **scaled masses of mitigated carbon** (i.e. M_1 and M_2) in a cost-effective manner. M_1 and M_2 are not **absolute mass reductions** because they are not based on counterfactual scenarios. The estimation of the **absolute mass reductions** in F_1 due to Rules 1 & 2 requires a post-audit that examines the partial differential equations for the carbon intensity of energy (E_1), and the carbon intensity of GDP (G), respectively, as shown in Table A3.

The stock and flow analysis of this study suggests that targeting "real net-zero" with the carbon pricing matrix is plausible — at least at a conceptual level — assuming that the XCC floor price (refer Figure 1) can be implemented by central banks.

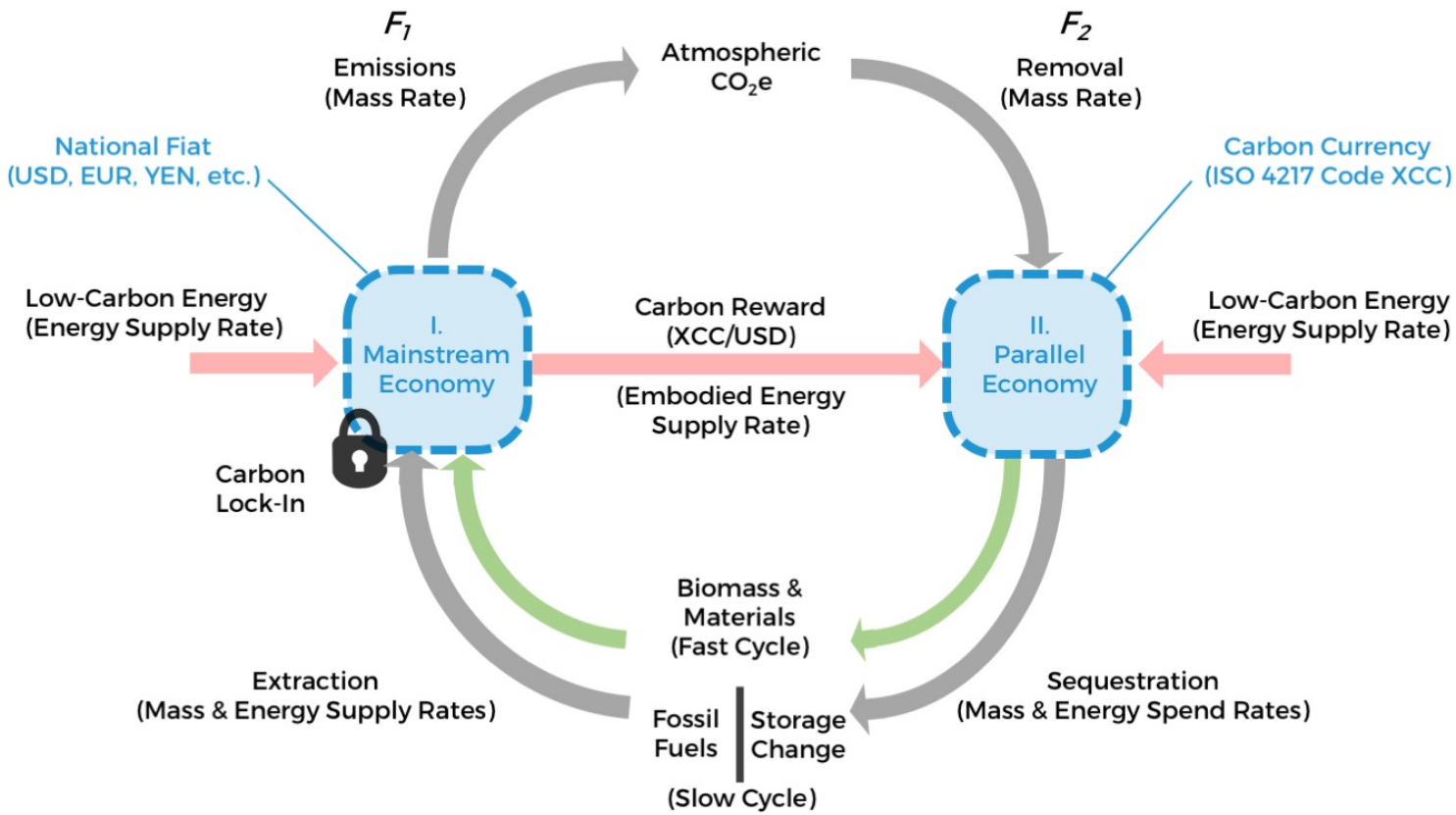

Figure A3. A stock-and-flow diagram showing the major carbon flows and energy inputs of civilization when the carbon reward policy is used to resolve the market failure in carbon. The carbon reward, denoted by the XCC/USD exchange rate, functions as a negative feedback on carbon emissions and on unsustainable energy consumption in the mainstream economy.

Table A3. The net carbon emissions of civilisation based on the modified Kaya identity

Mass Rate	Formula	Variables
F_1	$P \cdot \frac{G}{P} \cdot \frac{E_1}{G} \cdot \frac{F_1}{E_1}$	F_1 = mass rate of carbon emissions in the mainstream economy P = total human population G = world GDP E_1 = rate of primary energy production and usage in the mainstream economy
$\Delta F_{1,Energy}$	$\frac{d\left(\frac{F_1}{E_1}\right)}{dt} E_1 \times \Delta t$	$\Delta F_{1,energy}$ = absolute reduction in the mass rate of emissions (F_1) attributed to Rule 1 for rewarding cleaner energy production in the mainstream economy Δt = assessment period
$\Delta F_{1,GDP}$	$\frac{d\left(\frac{F_1}{G}\right)}{dt} G \times \Delta t$	$\Delta F_{1,GDP}$ = absolute reduction in the mass rate of emissions (F_1) attributed to Rule 2 for rewarding the consumption of cleaner goods and services in the mainstream economy Δt = assessment period
F_2	M_3	F_2 = absolute mass rate of carbon sequestration attributed to Rule 3 in the parallel economy M_3 = absolute mass rate of carbon removal by engineered, natural and hybrid methods (Rule 3)
M	$M_1 + M_2 + M_3$	M = total scaled mass rate of carbon mitigated and rewarded with carbon currency M_1 = scaled mass rate of carbon reduction based on cleaner energy supplies (Rule 1) M_2 = scaled mass rate of carbon reduction based on cleaner consumption (Rule 2)
F_{net}	$F_1 - F_2$	F = net rate of global carbon emissions

Footnotes

(a) The GCR policy may be expanded to offer rewards for population management but this option was excluded for reasons of brevity.

(b) The formulas in this table do not explicitly account for sudden or unexpected changes in the carbon cycle due to positive feedbacks in the climate system. Such events can be addressed through the GCR policy but other policies may be needed to manage the planetary energy balance through more direct means