

Principles and Requirements for Evaluating Carbon Credit Frameworks

SGFIN Whitepaper Series #05

Principles and Requirements for Evaluating Carbon Credit Frameworks

Desmond Tay, SGFIN

Michael Alexander, SGFIN

Syalabi Seet, SGFIN

Johan Sulaeman, SGFIN & NUS Business School

Abstract

As global climate initiatives like the Paris Agreement and the United Nations Sustainable Development Goals push for carbon neutrality, ensuring the quality and integrity of carbon credits is crucial, especially with the carbon credit market expected to grow fifteenfold by 2030. The increased demand has led to the growth and proliferation of verification frameworks, such as the Verified Carbon Standard, Gold Standard, and American Carbon Registry. These frameworks are essential for maintaining the environmental integrity of carbon credits and ensuring they contribute effectively to climate mitigation efforts. This paper proposes a robust methodology and a set of principles and requirements to evaluate these frameworks. Using this methodology, we examine dominant frameworks in the global carbon market and evaluate their ability to support high quality carbon credits.

About SGFIN

The Sustainable and Green Finance Institute (SGFIN) is a research institute established by National University of Singapore (NUS). SGFIN aims to develop deep research capabilities in sustainable and green finance with a focal point on Asia, and to provide thought leadership and shape sustainability outcomes in policymaking across the financial sector and the economy at large. Supported by exceptional domain experts across NUS, SGFIN equips businesses with critical cross-disciplinary knowledge, training, and toolkits to integrate sustainability dynamics into their business strategies and investment decisions to better quantify the environmental and social impacts of their business developments, operations, products, and services. In essence, SGFIN aims to help companies embed sustainability as a key pillar in their business decisions.

Recommended citation

Desmond Tay, Syalabi Seet, Michael Alexander and Johan Sulaeman. "Principles and Requirements for Evaluating Carbon Credit Frameworks", SGFIN Whitepaper #2024-05

Keywords: *Carbon Credit Framework, Carbon Markets, Project Evaluation, High Quality Carbon Credit*

© 2024 Sustainable and Green Finance Institute (SGFIN), National University of Singapore, Singapore.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form, or by any means, electronic, mechanical, photocopying, recording or otherwise, without prior written permission from the copyright owners.

The opinions expressed in this publication are the responsibilities of the authors and do not necessarily represent or reflect the position of SGFIN.

Sustainable and Green Finance Institute (SGFIN)

National University of Singapore
Innovation 4.0, 3 Research Link
#02-02, Singapore 117602

Editorial correspondence should be addressed to SGFIN@nus.edu.sg.

Foreword

As the world realises the urgent need to decarbonise its economies, global initiatives such as the Paris Agreement, which aims to limit warming to within 1.5 degrees Celsius compared to pre-industrial levels, and the yearly Conference of the Parties (COP) have been in the spotlight more than ever. However, many challenges remain in supporting the initiatives and meeting the goals set by these global discussions.



Carbon credits have become an important tool in the journey toward realizing the collective decarbonisation goal, which is essential for ensuring the survival of our environment and, consequently, our livelihoods. High quality carbon markets can incentivise companies and organisations to go beyond the minimum required to decarbonise their operations by creating an additional revenue stream. Moreover, they also allow companies that are unable to meet their short- to medium-term emission targets to offset the temporary shortfall by purchasing these credits.

The carbon credit market is projected to reach a valuation of US\$50 billion by 2030. Currently, there are 75 carbon pricing instruments globally, with various approaches to evaluating the effectiveness of projects. In light of recent controversies surrounding the dominant carbon crediting frameworks and the quality of the projects awarded credits using those frameworks, SGFIN has developed a set of critical carbon crediting principles, along with associated essential and beneficial requirements, to assess whether these frameworks are robust enough to ensure the issuance of high-quality carbon credits.

Moving forward, we hope that these principles and requirements will serve as a foundation for assessing both existing and future carbon crediting frameworks, helping investors to make more informed decisions regarding the integrity of the carbon credits generated in projects facilitated by these frameworks.

Prof. Sumit Agarwal
Managing Director, SGFIN

Low Tuck Kwong Distinguished
Professor of Finance at NUS Business School
Professor of Economics and Real Estate President of Asian Bureau of Finance and
Economic Research

Executive Summary

The Paris Agreement aims to limit global warming to below 2 degrees Celsius, with an ideal target of 1.5 degrees Celsius. Achieving these targets requires significant reductions in carbon emissions, and carbon credits form an important part of the solution in enabling the global community to meet these goals. Carbon credits provide a mechanism for both governments and corporations to offset emissions, helping them reach their climate objectives.

A study conducted by the Energy Studies Institute of the National University of Singapore projects that the demand for carbon credits will reach between 1.5 to 2 billion tonnes of carbon dioxide equivalent by 2030, and between 7 to 13 billion tonnes by 2050, Ref. [1]. This translates to a market valuation of 5 to 50 billion USD by 2030. As the demand for carbon credits increases, it is crucial to ensure that the quality of these credits is upheld to a high standard, ensuring the market's viability and effectiveness in combating climate change.

According to the World Bank, spanning both voluntary and compliance markets, Ref. [2], there are currently 75 carbon pricing instruments globally. Both markets are vital to the carbon market ecosystem. However, without necessary oversight, issues such as double issuances by multiple registries or credits awarded to non-additional projects could undermine the integrity of carbon crediting frameworks.

Without proper due diligence on which projects can generate carbon credits, there is a risk that the supply of low-quality credits could increase substantially. This oversupply would drive down credit prices, thus artificially reducing the perceived cost of carbon mitigation. Consequently, high quality carbon credits could become too cheap, failing to incentivise corporations to pursue “real” and “additional” emissions reduction activities.

This paper reviews multiple carbon crediting frameworks to identify best practices and its gaps. Through this review, four main pillars encompassing nine principles are established to define the Essential (“Must Have”) and Beneficial (“Good to Have”) requirements for producing high quality carbon credits.

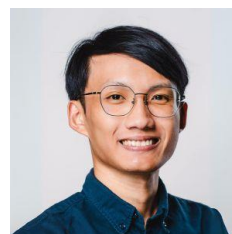
Three leading frameworks - ACR, the Verified Carbon Standard, and the Gold Standard - are assessed against these requirements, providing insights into the extent to which they facilitate the generation of high-quality credits and their genuine contribution to carbon abatement.

About the Authors

Desmond Tay is a Research Associate at the Sustainable and Green Finance Institute (SGFIN). He obtained his Bachelor of Engineering (Aerospace) from The University of New South Wales, and Master of Science in Sustainable and Green Finance from NUS. His research interest lies in energy transition projects and sustainability reporting.



Michael Alexander is a Research Analyst at SGFIN. His research interests lie in sustainable commodities and carbon credits market. He holds a B.Sc. in Quantitative Finance from NUS.



Syalabi Seet is a Research Associate at SGFIN. He obtained his Bachelor of Mechanical Engineering from the Nanyang Technological University and Master of Technology from NUS. He is currently involved in research on automated intelligence and data validation of greenhouse gas emission data. He is currently pursuing his PhD in Digital Financial Technology at NUS.



Johan Sulaeman is the Director of SGFIN. He is also a Dean's Chair and an Associate Professor in the Department of Finance at the NUS Business School. He currently serves as one of the Scientists at AIDF (Asian Institute of Digital Finance). He has been involved in designing and delivering executive programmes for large companies and financial institutions in the region, primarily on topics related to sustainability, finance, and technology. His current research focuses on corporate social and environmental performance. His research has appeared in top economics and business journals, and been covered in various international publications, including The Wall Street Journal and The New York Times. He also contributes opinion pieces to the Straits Times and Channel News Asia.



Definitions

Term	Definition
Common Practice	Common practice refers to the framework, widely accepted methods and procedures used by industries, organisations, and governments to measure, report, reduce and manage GHG emissions.
BAU (Business as Usual)	Business as Usual (BAU) refers to the standard operating procedures and practices that a project follows under normal circumstances without implementing any mitigation actions to address to greenhouse gas emissions.
Benefit Horizon	The period during which the benefits of a project, investment, or initiatives are expected to be realised. It defines the time frame over which positive externalities will manifest and continue to deliver value.
Buffer Pool	An account used as a reversal risk mitigation mechanism for projects. Each project deposits a determined quantity of carbon credits that can be used to offset unforeseen targets missed by the project.
Calibration Frequency	The regular interval at which measuring instruments or equipment are calibrated to ensure their accuracy and reliability. Calibration frequency is typically determined based on industry standards, manufacturer recommendations or specific projects.
Emission Factors	Emission factors are coefficients used to estimate the amount of greenhouse gases emitted per unit of activity or consumption.
Framework Setters	Organisations or bodies that develop, establish and maintain the regulations for awarding carbon credits in relation to the carbon offset projects executed.
GHG (Greenhouse Gas)	GHG refers to greenhouse gases that are released into the atmosphere contributing to the greenhouse effect, which traps heat and leads to global warming and climate change.
Implementation Barrier	Implementation barriers are obstacles that impede effective execution and operation of the project.
Leakage	A decrease in sequestration or increase in GHG emissions outside project boundaries resulting from project implementation.
Materiality Threshold	The threshold to determine the significance of errors. Errors below the limit are considered immaterial and do not affect the overall accuracy or the GHG reporting.

Term	Definition
Permanence Period	The permanence period refers to the duration for which the effects of the reduced or removed carbon emissions remain and continue to have its intended impact.
Project Milestone	A significant event or checkpoint in a project that marks the completion of a major phase or deliverable. Milestones are used to measure progress and ensure that the project stays on track by highlighting key moments, such as the start or end of a phase, the achievement of important goals, or the delivery of critical outcomes.
Project Term	The period over which estimated climate benefits are assumed to be achieved if project activities are carried out as planned.
Reversibility	An intentional or unintentional event that results in the emissions into the atmosphere of stored or sequestered carbon dioxide equivalent for which carbon credits were issued to assessed projects.
Stakeholder	Refers to individuals, groups or institutions that have a stake, or an interest in the project activity – that may be affected by it (either positively or negatively) and be in a position to influence its outcomes.
Technological Practices	The application of technology-driven methods, tools or systems in specific processes or activities to achieve desired outcomes. Encompasses the techniques and strategies used to implement technology effectively guided by best practice, industry standards, and innovation.
Validation Body	An accredited organisation that has been approved by the board to perform GHG verification activities for the projects assessed.
Verification Team	The systematic, independent, and documented assessment by a qualified and impartial third party of the GHG statement for a specific reporting period.

CONTENTS

1	Desired Outcomes	1
2	The Role of Carbon Credits in Global Climate Action	2
3	Upholding Carbon Market Integrity	4
3.1	Four Pillars of Critical Principles	5
3.2	Requirements of Critical Principles	6
4	Scoring Methodology for High-Quality Carbon Credits: A Balanced Approach	12
4.1	Evaluation of Existing Frameworks	13
4.2	The Verified Carbon Standard	13
4.3	American Carbon Registry	16
4.4	The Gold Standard.....	20
4.5	Differences Among Frameworks.....	22
4.6	Commonality Among Frameworks.....	23
5	Conclusion	25
6	References	26
	Appendix A	A-1
	Appendix B	B-1
	Appendix C	C-1

FIGURES

Figure 1 – The VCS Framework Evaluation of only "Essential" Requirements	14
Figure 2 – The VCS Framework Evaluation with Consideration of All Requirements	16
Figure 3 - The American Carbon Registry Framework Evaluation of only "Essential" Requirements	17
Figure 4 - The ACR Framework Evaluation, Considering All Requirements	19
Figure 5 - The Gold Standard Evaluation of only "Essential" Requirements	20
Figure A-1 - Results of Correlation Analysis	A-1

TABLES

Table 1 – Desired Outcomes	1
Table 2 – Principles and Definitions	5
Table 3 – Pillars and Principles	5
Table 4 – Requirements for Evaluation	7
Table 5 – Total Carbon Credits Issued	13
Table 6 – Summary of the VCS Evaluation of only "Essential" Requirements	14
Table 7 – Summary of the VCS with Consideration of All Requirements	15
Table 8 – Summary of The American Carbon Registry Evaluation of only "Essential" Requirements	17
Table 9 – Summary of The ACR Framework Evaluation, Considering All Requirements	19
Table 10 – Summary of the Gold Standard Evaluation of only "Essential" Requirements	20

APPENDICES

Appendix A – Clustering Methodology for Co-Relation of Principles
Appendix B – Evaluation of Carbon Crediting Frameworks
Appendix C – Documents Assessed

1 Desired Outcomes

This study aims to identify the critical principles along with essential and beneficial requirements for a carbon credit framework that facilitates the development of high-quality carbon credits. The expected outcomes are outlined in Table 1.

Table 1 – Desired Outcomes

	Desired Outcomes
1	Permanence and Risk Management: Verify the permanence of GHG emission reductions or removals, with measures to address and compensate for potential reversals, using robust scientific methods to quantify these activities conservatively.
2	Science-Based Transparent Standards: Use AI tools and innovations to establish science-based standards and transparent infrastructure for high-quality GHG emission reduction and removal credits, ensuring transparent, public access to information and consistent methodologies across projects.
3	Robust Project Cycle and Effective Governance: Promote a robust project cycle with transparent, simplified registration and carbon credit issuance procedures, alongside independent third-party validation and verification to ensure accuracy, accountability, and effective governance.
4	Additional and Diverse Projects: Ensure additionality and enable a greater variety of project activities by streamlining methodologies, incorporating efficient monitoring, reporting, and verification (MRV) approaches, and incorporating measures to prevent harm to the environment or society.
5	Incentivising Participation in Emission Mitigation to Achieve Net Zero: Facilitate and incentivise participation in GHG emission mitigation efforts, contributing to the UN Sustainable Development Goals (SDGs) and the objective of real carbon abatement achieving net zero GHG emissions by mid-century.

2 The Role of Carbon Credits in Global Climate Action

Carbon credits have become a pivotal instrument in global efforts to combat climate change. Functioning as tradeable permits, each carbon credit represents the reduction or removal of one metric ton of carbon dioxide (CO₂) from the atmosphere, Ref [3]. The growing demand for such credits arises from the increasing recognition that achieving carbon neutrality is imperative to limit climate change, as emphasised by international developments like the Paris Agreement and the United Nations Sustainable Development Goals (SDGs).

The critical need for carbon credits stems from the urgency to decarbonise while balancing economic growth for both developed and developing economies. The Paris Agreement has set ambitious targets for emissions reductions, and carbon credits offer a viable mechanism for countries and entities to meet their climate goals. By purchasing carbon credits, enterprises can compensate for their emissions by supporting projects that reduce or remove carbon dioxide emissions.

The surge in demand for carbon credits is driven by heightened environmental awareness and the pressing need for scalable solutions to offset emissions. Projections suggest that demand for carbon credits could increase by a factor of 15 by 2030, potentially valuing the market at upwards of US\$50 billion, Ref [4].

Participants in the carbon credit market encompass a diverse range of stakeholders. Buyers typically include companies that have committed to eliminating part or all of their greenhouse gas (GHG) emissions but are unable to do so without sacrificing the efficiency of their operations. Therefore, the purchase of carbon credits is a reasonable intermediate mechanism to meet their short to medium-term emissions reduction targets, Ref [3].

Sellers of carbon credits are typically project developers who have implemented initiatives which demonstrably reduce or remove carbon emissions such as reforestation. This reduction or removal allows them to sell carbon credits, creating an alternative revenue stream that can be reinvested into future emissions reduction or removal projects, Ref [5].

Ensuring that carbon credits are awarded only after satisfying rigorous verification frameworks is essential for the market's integrity and effectiveness. Without stringent frameworks to ensure that carbon credits demonstrate principles such as "Real", "Additional" and "Permanent", low-quality carbon credits could flood the market, potentially devaluing all carbon credits including high quality ones. This would have far reaching consequences, as the incentive to pursue "real" and "additional" carbon emission reduction projects would be greatly diminished, and the potential risks of greenwashing would increase significantly, Ref [6].

This paper delves into the existing frameworks that certify carbon credit issuance, assessing their robustness and effectiveness in ensuring that only high-quality credits are issued and traded in carbon markets. Through this evaluation, the study aims to provide insights into best practices for sustaining the integrity and efficacy of carbon credit markets.

3 Upholding Carbon Market Integrity

We identify nine principles that are critical to a high-quality carbon credit framework, which would facilitate the issuance of high-quality carbon credits. We reviewed widely used carbon credit frameworks, including the American Carbon Registry, Verra's VCS, the Gold Standard, the Climate Action Reserve, and the Global Carbon Council, and observed that although different methodologies and guiding principles exist, certain concepts were consistently emphasised across these frameworks.

In addition, we incorporate several principles that would facilitate more financing to projects and initiatives with more potential to generate high quality carbon credits.

Table 2 lists the nine critical principles and their respective definitions.

Table 2 – Principles and Definitions

Principle	Definition	Ref.
Real	Confirms that emissions reductions are based on actual, verifiable reductions, not hypothetical scenarios or future projections.	Ref [7]
Permanent	Guarantees that the carbon reduction or removal is lasting and will not be reversed over time, ensuring long term benefits.	
Measurable	Requires that the emissions reductions or removals are quantitatively measured using established, transparent, and verifiable methods.	Ref [7]
Consistent	Ensures that standardised methodologies are applied uniformly across projects, allowing for comparability and reliability of emissions data.	Ref [7]
Traceable	The ability to track the lifecycle of a carbon credit from its origin through its certification, issuance, sale, and eventual retirement.	
Additional	Ensure that the carbon reduction or removal would not have occurred without the incentive provided by the carbon credit.	Ref [8]
Transparent	Require full public disclosure of project data, methodologies, and verification processes to ensure open access to information for stakeholders.	Ref [9], [10]
Precise	Ensures a high degree of accuracy in measurement and reporting of emissions reductions, minimising uncertainties and errors in the data.	Ref [10]
Legally & Financially Sustainable	Ensure the project is legally sound and financially viable over time, allowing for long-term operational success and continued emissions reduction.	Ref [7], [10]

For each principle, we identify the best practices in existing frameworks as well as unaddressed potential gaps. These are categorised into “Essential” and “Beneficial” requirements for a high-quality carbon credit framework.

3.1 Four Pillars of Critical Principles

We use an analytical approach to combine these principles into four clusters as illustrated in Table 3. The analytical process is described in more detail in Appendix A.

Table 3 – Pillars and Principles

Pillar	Principle
Climate Impact	Real
	Permanent
Methodology	Measurable
	Consistent
	Traceable
Authenticity	Additional
	Transparent
	Precise
Feasibility	Legally & Financially Sustainable

These four pillars encompass the essential qualities that the framework must consider when evaluating projects for high-quality carbon credit generation.

- The Climate Impact pillar assesses whether a framework can effectively reduce or remove emissions.
- The Methodology pillar evaluates whether the framework can systematically assess projects and ensure that any emission reductions or removals are calculated and verified consistently.
- The Authenticity pillar ensures that the projects, and consequently the emissions measurements being evaluated, are genuine and not at risk of inflated or deflated claims.
- The Feasibility pillar addresses whether the evaluated projects can be sustained in the long term, considering financial, regulatory, or operational factors.
-

3.2 Requirements of Critical Principles

When assessing a carbon crediting framework's ability to generate high quality carbon credits, the framework is evaluated based on a set of requirements derived from the nine identified principles. These requirements are split into two levels of significance: "Essential" and "Beneficial". This approach allows frameworks to be acknowledged for meeting crucial requirements that are essential for the generation of high-quality carbon credits, while also rewarding those that fulfil additional requirements, which aid in ensuring the quality of the credits awarded.

We view "Essential" requirements as non-negotiable characteristics in ensuring that the carbon credits issued to projects that are indeed "Additional" and "Real". We can consider these requirements as "Must-Have". In addition, "Beneficial" requirements, while not as critical, enhances the framework's capacity to generate high quality carbon credits. We can consider these requirements as "Good-to-Have".

Table 4 illustrates the requirements based on the scoring system discussed earlier.

Table 4 – Requirements for Evaluation

Principle	Essential	Beneficial
Additional	<ol style="list-style-type: none"> 1. Require that the GHG emission reductions and / or removals generated by the project are materially above and beyond Business as Usual (BAU) 2. Specify a robust methodology that satisfies scientific requirements to determine the baseline data and the resulting additionality for the project. 	<ol style="list-style-type: none"> 1. Require that the project's mitigation actions go beyond common practice 2. Require a clear description of at least one implementation barrier that will be overcome by the project
Real	<ol style="list-style-type: none"> 1. Require that the GHG emission reductions and / or removals generated by the project are quantifiable and recorded accurately so that they are directly verifiable. 2. Require that the measured effects are verified using a robust methodology that satisfies scientific requirements. 3. Provide a clear set of requirements regarding the documentation of evidence of the project's effects. 	<ol style="list-style-type: none"> 1. Require a detailed discussion of how the project's impacts will be verified through stakeholder confirmation. 2. Require a clear timeframe and milestones of the project's planned progress. 3. Require a clear description of how each milestone will be verified, including the description of technology and methods that will be used.
Measurable	<ol style="list-style-type: none"> 1. Require a clear and thorough documentation of the project (including its design, scope, and measurement methodology) to allow for replication and outside review. 2. State the maximum permissible errors allowed in the measurement of specific effects. 3. Prescribe the acceptable timeframe and frequency of measurements of specific effects. 	<ol style="list-style-type: none"> 1. Prescribe a standard for the quality of the measurement equipment and the required (re)calibration frequency. 2. Require adherence to common practice for sampling methodology and statistical confidence

Principle	Essential	Beneficial
Permanent	<ol style="list-style-type: none"> 1. Ensure that the project has a lasting and permanent effect on the reductions and/or removals of GHG 2. Require that conservative and realistic assumptions are used in the framework methodology, accounting for various risk factors such as reversibility and leakage, regardless of intentionality. 3. Prescribe specific deadlines for project owners to state the minimum project term, the benefit horizon, and the start of the project's permanence period. 	<ol style="list-style-type: none"> 1. Provide a clear set of guidelines for the discussion of non-permanence risks as per project methodology approved by the framework 2. Require process of the deposit of credits into buffer pool to mitigate against risk to permanence to be laid out
Transparent	<ol style="list-style-type: none"> 1. Require a clear and thorough documentation of the project (including its design, scope, and measurement methodology) to allow for replication and outside review. 2. Require independent framework setters, measurement and verification team, and project owners who have no conflict of interest with all other parties involved. 3. Require adherence to the materiality threshold determined by the framework. 	<ol style="list-style-type: none"> 1. Require the accreditation of the validation entity performing independent verification 2. Require a clear description of the audit team, with specific roles and responsibilities of each team member 3. Require a clear description of the procedures that will be used to track the project's GHG emission reductions and/or removals, and how these are transferred to other parties aiming to meet their own targets. 4. Provide a clear set of guidelines for the discussion of measured and expected impacts within the verification report

Principle	Essential	Beneficial
Precise	<ol style="list-style-type: none"> 1. Require a clear discussion of the process undertaken to validate the accuracy of the measurement of the project's effects. For example, requiring that the emission factors used in the measurements are derived from a scientific peer-reviewed sources, are appropriate for the specific GHG emitter, and account for any potential uncertainty. 2. Prescribe a minimum materiality threshold 3. Require adherence to the benchmarks, specific and quantifiable goals that are required by the approved methodology. 4. Require a validation of the measured effects of the project using methodologies evaluated and approved by the framework setter. 	<ol style="list-style-type: none"> 1. Provide a clear set of guidelines for the discussion of the avoidance and/or elimination of potential biases in the quantification methodology of GHG emissions, including the use of site-specific emission factors and the inputs for the estimation of the measurement of baseline and future emissions. 2. Require a clear discussion of how the quantification methodology will leverage technological practices to enhance its accuracy, while also addressing the potential risks of technology failure in this context. 3. Require a thorough documentation verifying the level of assurance required through documentation. 4. Require that any future deviations from the proposed program methodology approved by the framework does not reduce the conservativeness of the quantification of emission reductions or removals.
Consistent	<ol style="list-style-type: none"> 1. Require a consistent methodology that can be applied across projects of the same type 2. Require measurements and data sampling methods of common variables to be conducted consistently to enable easy comparison across assessed projects. 	<ol style="list-style-type: none"> 1. Require high-quality sources of information and comparison for data with high levels of uncertainty to elicit a greater confidence on the assurance process. 2. Require existing projects to update their project design description document when any changes to the Standard or Methodology is made

Principle	Essential	Beneficial
	3. Require a clear description of the methodology used for measurement. Methodology is to be made publicly available to ensure consistency amongst all projects evaluated under the framework.	
Traceable	1. Issue a unique serial number to each unit of carbon credit issued. 2. Prescribe the use of a reputable carbon registry to track the issuance, ownership, and retirement and/or cancellation of carbon credits. 3. Require availability and public access to the carbon registry information so that the credits are verifiable with other registries.	1. Promote coordination among registries to ensure that a specific project (or activity) is not registered with more than one registry.
Legally & Financially Sustainable	1. Require a thorough discussion regarding viability and self-sufficiency of the project, particularly once the project initial funding runs out and / or carbon related revenues (e.g. carbon credits) are absent. Consider the absence of carbon revenues for project viability and determine if projects are self-sufficient once initial funding is used 2. Require a thorough assessment of whether the proceeds from the carbon credits (e.g., subsidies and carbon market potentials) associated with the project's location jurisdiction, can cover the costs of the proposed mitigation actions.	1. Require a detailed contingency plan to address potential changes in regulations or governmental structures 2. Require a discussion of potential situations where targeted GHG emissions reductions or removals are not met, and the proposed viable mechanisms to address these situations. 3. Promote publicly accessible mechanisms to track and evaluate the performance and success rate of project owners in ongoing and completed GHG emission reduction/removal projects

Principle	Essential	Beneficial
	<p>3. Require a contingency plan if the resulting revenues from carbon credits, subsidies, and tax incentives, are not sufficient to cover the proposed mitigation actions.</p> <p>4. Require that the project owners have (1) complied with all current policies and regulations and (2) considered potential future changes in policies and regulations.</p>	

4 Scoring Methodology for High-Quality Carbon Credits: A Balanced Approach

"Essential" requirements that are fulfilled are awarded 1 point each while "Beneficial" requirements, while not as critical, enhances the framework's capacity to generate high-quality carbon credits is awarded 0.5 points each if met. The scoring system takes a balanced approach, recognising frameworks that not only meet essential "Essential" requirements but also those that fulfil additional criteria, thereby improving the overall quality of carbon credits from projects evaluated under the framework.

As the use of carbon credits has not been adopted by many companies, an initial 60% threshold is used to evaluate if the carbon crediting framework meets the necessary requirements to generate high-quality carbon credits for a market that is still developing. Ideally, in a mature market, an 80% threshold of the requirements would be the minimum that should be met.

For this study, the frameworks are evaluated against the "Essential" requirements with a fulfilment threshold of 60%. If the majority of principles meet this threshold, a further evaluation with a threshold of 80% and consideration of all requirements will follow.

The detailed results for each requirement are reported in Appendix B.

4.1 Evaluation of Existing Frameworks

Verra's VCS, the American Carbon Registry, and the Gold Standard were chosen because they each approach the generation of carbon credits for evaluated projects differently. Each framework has its own strengths and weaknesses, making it essential to evaluate them to gain a well-rounded perspective on the generation of high-quality carbon credits. In addition, the three frameworks collectively issue more than 92% of the global carbon credits issued.

Table 5 illustrates the total percentage of carbon credits issued under the American Carbon Registry, the Verified Carbon Standard (VCS) and the Gold Standard respectively, compared to the total number of projects assessed globally.

Table 5 – Total Carbon Credits Issued

Framework	The American Carbon Registry ⁴⁾	The Verified Carbon Standard ¹⁾	The Gold Standard ²⁾	Total (Global) ³⁾
Carbon Credits Issued (Millions)	132	1,276	373	1,919
Carbon Credits Issued (Percentage)	6.88 %	66.49 %	19.44 %	

Notes:

1) Refer to Ref. [11]

2) Refer to Ref. [12]

3) Refer to Ref. [1]

4) Refer to Ref. [13]

Evaluations of frameworks for each requirement and the documents used for evaluation are summarised in Appendix B and Appendix C respectively.

4.2 The Verified Carbon Standard

The Verified Carbon Standard (VCS) is currently the most widely used carbon crediting framework globally, with over a billion carbon credits issued and 500 million carbon credits retired, Ref [14]. A recent study in The Guardian has raised eyebrows about VCS's credit issuance procedures and the integrity of the corresponding carbon credits. The study claims that more than 90% of the rainforest offset credits issued by the VCS for projects undertaken by large corporations such as Disney and Shell were incorrectly awarded, Ref [15]. This study amplifies the importance of examining the VCS framework, particularly given its market prominence.

Table 6 and Figure 1 summarise the framework evaluation for the VCS, considering only the "Essential" requirements. The results show that the VCS meets the 60% threshold for six principles - "Real," "Permanent," "Measurable," "Traceable," "Additional", and "Transparent". With the 60% fulfilment threshold established for a market that is still developing. We apply a higher threshold of 80% to analyse the results,

as described in Chapter 4. With this higher threshold, VCR meets the requirement for only one principle - "Real".

Table 6 – Summary of the VCS Evaluation of only "Essential" Requirements

The Verified Carbon Standard				
Pillar	Principle	Fulfilment Rate of Requirements	High Quality Carbon Credit Criteria > 60%	High Quality Carbon Credit Criteria > 80%
Climate Impact	Real	100.00%	Pass	Pass
	Permanent	66.67%	Pass	Fail
Methodology	Measurable	66.67%	Pass	Fail
	Consistent	50.00%	Fail	Fail
	Traceable	66.67%	Pass	Fail
Authenticity	Additional	75.00%	Pass	Fail
	Transparent	66.67%	Pass	Fail
	Precise	25.00%	Fail	Fail
Feasibility	Legally & Financially Sustainable	50.00%	Fail	Fail

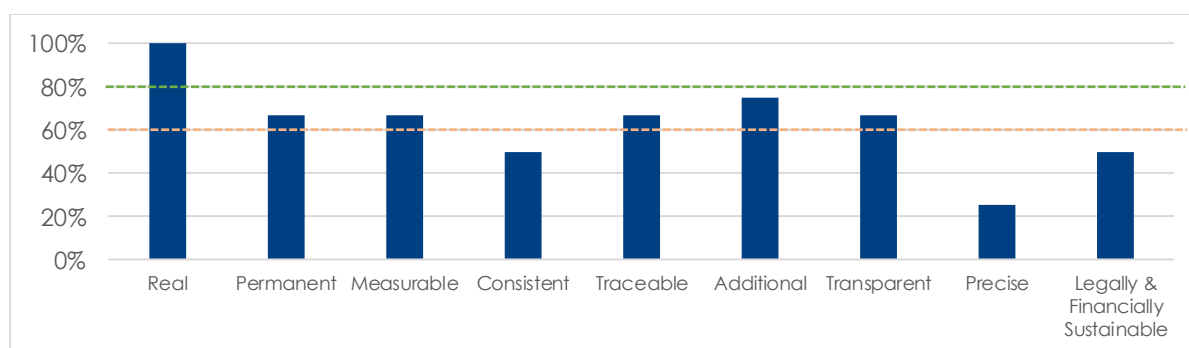


Figure 1 – The VCS Framework Evaluation of only "Essential" Requirements

The VCS framework requires that any actions carried out by the evaluated projects result in reductions or removals of GHG emissions that would not have occurred if the project had not been implemented. This is essential, as it ensures that the actions claimed are additional and would not have happened under Business-As-Usual approach.

Verra's VCS also mandates that project documentation be clearly presented and made public. This allows external stakeholders to scrutinise the methodology applied or understand how emissions data is calculated, and thus assess whether the intended goals of the project have been achieved. Moreover, all Validation/Verification Bodies conducting the evaluations must be accredited, thereby ensuring that these verifiers are qualified for the task.

However, gaps remain in the framework, such as not fully specifying the scientific requirements for projects to define how the baseline is determined, how additionality is achieved, and when the benefit horizon begins. This could lead to shifting goalposts, where projects may under report the baseline and thus inflate claims of additionality, benefits, and longevity. In addition, requirements such as the need to encourage coordination with other registries to prevent issues like double counting and double issuances are not fulfilled.

For the principles in which VCS fails to satisfy the minimum threshold, it is evident that it has the lowest score in the "Precise" principle at just 25%. Missing requirements, such as the use of methodologies approved by the framework setter and clearly outlining the process for validating these measurements, contribute to this low score. This could result in inaccurate measurements being taken and inaccurate reporting of the benefits achieved by the project. Ultimately, this could threaten the integrity of the project and its intended goals.

In addition, for the "Legally & Financially Sustainable" principle, the need for project owners to ensure compliance with all current policies and regulations, as well as to consider future changes and the consideration of the use of carbon revenues are the only requirements that has been satisfied. This is especially concerning, as there is a serious deficiency within the framework regarding the long-term operational or financial feasibility of the evaluated projects. "Essential" requirements, such as an assessment to draw up a contingency plan should carbon revenue be exhausted prematurely are missing from the framework.

A second part of the analysis covering both "Essential" and "Beneficial" requirements is performed for VCS as it meets the 60% threshold for more than half the principles considering only the "Essential" requirements. Table 7 and Figure 2 present the evaluation of the VCS framework considering all requirements.

Table 7 – Summary of the VCS with Consideration of All Requirements

The Verified Carbon Standard				
Pillar	Principle	Fulfilment Rate of Requirements	High Quality Carbon Credit Criteria > 60%	High Quality Carbon Credit Criteria > 80%
Climate Impact	Real	66.67%	Pass	Fail
	Permanent	75.00%	Pass	Fail
Methodology	Measurable	62.50%	Pass	Fail
	Consistent	50.00%	Fail	Fail
	Traceable	57.14%	Fail	Fail
Authenticity	Additional	83.33%	Pass	Pass
	Transparent	65.00%	Pass	Fail
	Precise	41.67%	Fail	Fail
Feasibility	Legally & Financially Sustainable	36.36%	Fail	Fail

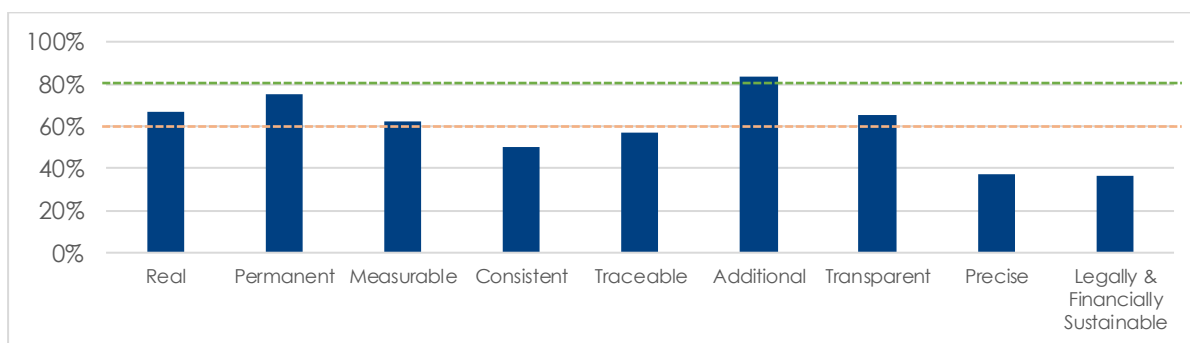


Figure 2 – The VCS Framework Evaluation with Consideration of All Requirements

VCS satisfies the fulfilment threshold of 60% for all requirements for five out of the nine principles VCS satisfies. These results indicate that the VCS provides a certain level of confidence that the carbon credits it issues are of high quality in a developing carbon market. Similar to Table 6, when only the “Essential” requirements were considered, raising the threshold to 80% results in the VCS meeting the fulfilment threshold for only one principle. This suggests that the framework still has some way to go before it can instil confidence that the quality of the credits it issues is sufficient for a mature carbon market.

It is worth mentioning that although the VCS satisfies all the “Essential” requirements for the “Real” principle, it still does not fulfil all the “Beneficial” requirements. The lack of “Beneficial” requirements such as the declaration of timelines or stakeholder confirmation could raise doubts about the legitimacy of the reported emission reductions or removals.

4.3 American Carbon Registry

The American Carbon Registry (ACR) is the world's first private voluntary carbon registry, founded in 1996, Ref. [16]. It is also the first market-wide cap-and-trade program for carbon emissions operating in the U.S. market, Ref. [17]. As a pioneer in the carbon market industry and the first mover in North America, evaluating the ACR would provide this study with a different perspective.

Table 8 and Figure 3 illustrate the framework evaluation for the ACR for only the “Essential” requirements. With a 60% fulfilment threshold, it satisfies the passing criteria for eight out of the nine principles. The VCR meets all the “Essential” requirements for “Real”, “Additional” and “Transparent”

Table 8 – Summary of The American Carbon Registry Evaluation of only “Essential” Requirements

The American Carbon Registry				
Pillar	Principle	Fulfilment Rate of Requirements	High Quality Carbon Credit Criteria > 60%	High Quality Carbon Credit Criteria > 80%
Climate Impact	Real	100.00%	Pass	Pass
	Permanent	83.33%	Pass	Pass
Methodology	Measurable	83.33%	Pass	Pass
	Consistent	66.67%	Pass	Fail
	Traceable	66.67%	Pass	Fail
Authenticity	Additional	100.00%	Pass	Pass
	Transparent	100.00%	Pass	Pass
	Precise	75.00%	Pass	Fail
Feasibility	Legally & Financially Sustainable	25.00%	Fail	Fail

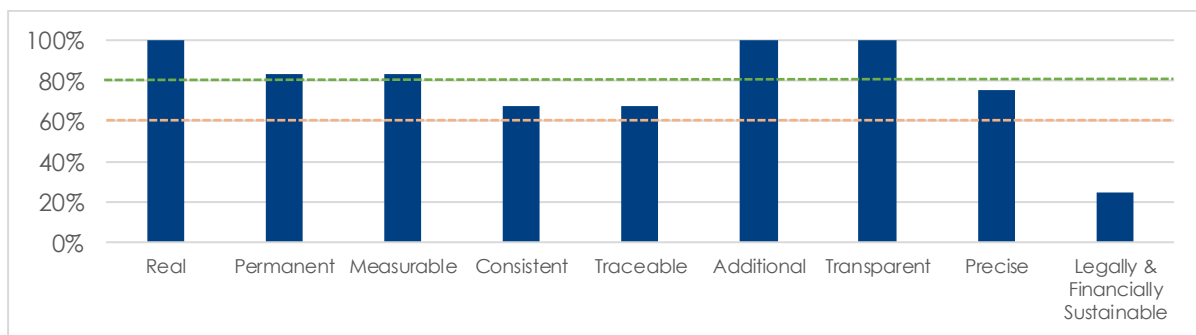


Figure 3 - The American Carbon Registry Framework Evaluation of only “Essential” Requirements

It is worth noting that even though the ACR has met the passing criteria for most of the principles it neither requires a clear procedure for tracking emission reductions or removals, nor mandates reporting on whether these benefits were transferred to another party or project. In addition, the ACR does not require projects to disclose whether actions have been taken to eliminate bias in the inputs or factors they have used for emissions calculations. Moreover, these factors need not be verified. This lack of requirements could undermine the confidence on the carbon credit issued.

One of the requirements of the “Consistent” principle is that methodologies and sampling methods be applied equally to projects of the same type. While ACR generally requires this, the framework imposes different requirements for different regions. For example, in Canada, baseline data must be calculated forward over a century, while in the United States, it only needs to cover the same duration as that of the project term, Ref [18], [19]. This may result in variations in outcomes for similar projects and emissions, making it difficult for external parties to evaluate the projects.

With respect to the “Traceable” principle, the ACR mandates the use of a public registry and the tagging of unique serial to each carbon credit. However, it provides flexibility for credits to be possibly issued under two registries. This might pose potential difficulty in tracing credits due to the need to compare information across several registries. Furthermore, if safeguarding measures are not adhered to, double counting might occur which can harm the confidence in the legitimacy of credits and affect traceability in the long term.

The framework requires project owners to set the materiality threshold and its expected impacts from the onset of the project. Setting this threshold from the outset ensures that errors remain within tolerance, minimising potential disruptions while also enhancing stakeholder confidence. The establishment of such a threshold would encourage ongoing monitoring of the project's implementation progress and enable swift actions to be taken if the threshold is breached.

The ACR fails to meet the 60% passing threshold when considering only the “Essential” requirements in the “Legally & Financially Sustainable” principle. The only “Essential” requirement that the ACR meets is the mandate for projects to assess their long-term sustainability without relying on revenues generated from the initial sale of carbon credits. However, the ACR does not specify what should happen if carbon revenues are exhausted at any point during the project's duration. Additionally, the ACR does not mandate contingency plans for situations where the project's intended financial plan does not materialize as intended. These oversights could increase the risk that a certified project may face difficulties in execution and ultimately fail to achieve its intended outcomes.

With the ACR passing a large majority of the principles with the fulfilment threshold of 60% for the consideration of only “Essential” requirements, a more stringent threshold of 80% was applied. The number of principles for which the ACR can meet the fulfilment criteria is reduced to five, with the “Consistent”, “Traceable” and “Precise” principles dropping out. This would indicate that although the ACR meets the requirements for an emerging and developing carbon market, it may not be sufficient for a developed marketplace. However, it must be noted that the ACR still meets the fulfilment criteria for the majority of the principles even with an 80% fulfilment threshold.

With the ACR meeting the 80% threshold for a plurality of principles considering only the “Essential” requirements, we conduct a further evaluation considering all requirements. Table 9 and Figure 4 illustrate the summary of the framework evaluation for the ACR.

Table 9 – Summary of The ACR Framework Evaluation, Considering All Requirements

The American Carbon Registry				
Pillar	Principle	Fulfilment Rate of Requirements	High Quality Carbon Credit Criteria > 60%	High Quality Carbon Credit Criteria > 80%
Climate Impact	Real	77.78%	Pass	Fail
	Permanent	75.00%	Pass	Fail
Methodology	Measurable	87.50%	Pass	Pass
	Consistent	56.25%	Fail	Fail
	Traceable	57.14%	Fail	Fail
Authenticity	Additional	100.00%	Pass	Pass
	Transparent	70.00%	Pass	Fail
	Precise	75.00%	Pass	Fail
Feasibility	Legally & Financially Sustainable	18.18%	Fail	Fail

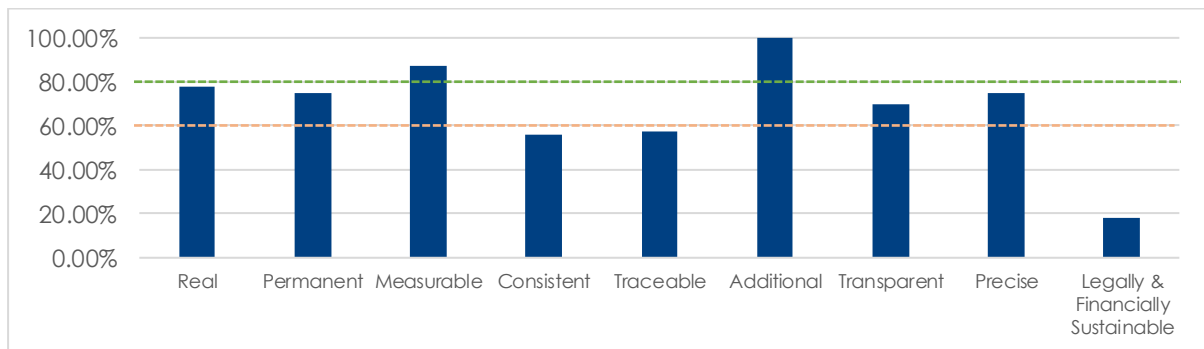


Figure 4 - The ACR Framework Evaluation, Considering All Requirements

With a 60% fulfilment threshold, the ACR meets the criteria for six out of the nine critical principles. This suggests that the ACR can provide a certain level of assurance that the credits in a developing marketplace are of high quality. However, when the fulfilment threshold is raised to 80%, only three principles meet the requirements. This indicates that although ACR is the best-performing framework among the three evaluated, the framework still needs additional improvements to ensure high-quality carbon credits in a mature market.

A general decrease in the fulfilment rate is observed when all requirements are considered. Eight out of the nine principles show a decline in fulfilment rate, with the largest drop of 30% in the "Transparent" principle. This implies that a significant number of "Beneficial" requirements are not being satisfied, suggesting that despite ACR's strong fundamental framework, improvements can still be made in more specific areas to enhance the protection of the credit's integrity.

Notably, the "Additional" principle meets all requirements, both "Essential" and "Beneficial". This would demand that the project owners cannot simply meet the

minimum requirements or follow industry norms. Its three-pronged approach to additionality requires detailed proof of going beyond regulatory and common practice norms, as well as overcoming any implementation barriers, Ref [7]. This provides further assurance on the additionality aspect of projects certified under the ACR.

4.4 The Gold Standard

The Gold Standard is one of the largest and more widely respected carbon crediting frameworks. It has faced its fair share of criticisms, particularly for being less accessible to smaller projects due to the complexity of its framework, Ref [20]. In addition, it has been criticised for being too focused on renewable energy, potentially overlooking other projects where the benefits involve carbon reduction or removal. Compared to VCS, which is more focused on monitoring and verifying progress, the Gold Standard is more outcome-driven, thereby offering a different perspective on carbon credit frameworks, Ref [20].

Table 10 – Summary of the Gold Standard Evaluation of only “Essential” Requirements

The Gold Standard			
Pillar	Principle	Fulfilment Rate of Requirements	High Quality Carbon Credit Criteria > 60%
Climate Impact	Real	66.67%	Pass
	Permanent	0.00%	Fail
Methodology	Measurable	16.67%	Fail
	Consistent	33.33%	Fail
	Traceable	33.33%	Fail
Authenticity	Additional	75.00%	Pass
	Transparent	66.67%	Pass
	Precise	50.00%	Fail
Feasibility	Legally & Financially Sustainable	37.50%	Fail

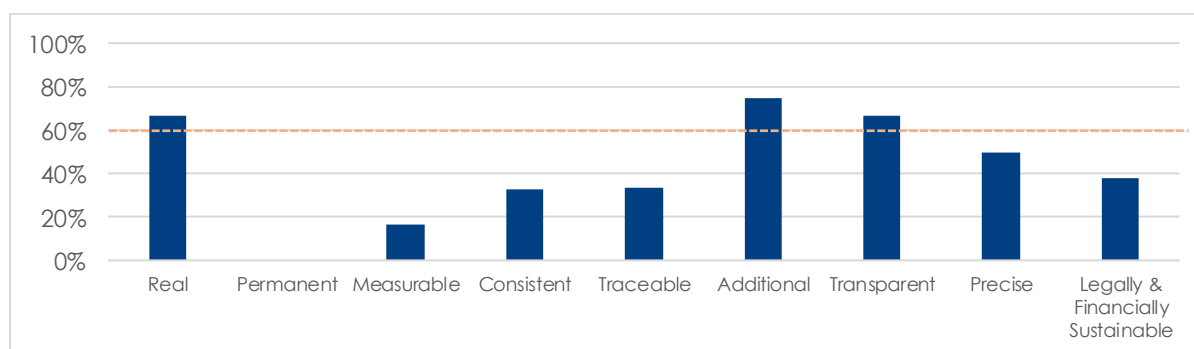


Figure 5 - The Gold Standard Evaluation of only “Essential” Requirements

Table 10 and Figure 5 illustrate the summary of the framework evaluation for the Gold Standard considering only “Essential” requirements. Of the three evaluated frameworks, the Gold Standard is the worst performing framework. With a fulfilment threshold of 60%, it satisfies the criteria for only three critical principals. This potentially highlights fundamental issues with the framework’s ability to ensure the issuance of high-quality carbon credits.

Even for principles in which it performs the best - “Additional,” “Transparent,” and “Real”—there are still clear gaps within the framework. The mandate for GHG emission reductions or removals generated by the project to be quantifiable and accurately recorded is missing from the Gold Standard framework. This could lead to shifting standards in how data regarding emission reductions/removals is recorded and used to determine whether the removal or reduction occurred.

Furthermore, the Gold Standard does not provide clear requirements on how the measurements and expected impacts of a project should be presented in the verification report. This could lead to instances where unfavourable information is conveniently or inadvertently omitted from the verification report.

However, the framework does provide guidance for documenting evidence of the project’s effects. The mandatory use of a robust methodology to measure the project’s benefits would give external parties more confidence that the beneficial effects have occurred.

The framework only attains a fulfilment rate of 50% in the “Precise” principle. It is imperative for the evaluated project to adhere to a minimum materiality threshold. This allows errors to remain within tolerance without sacrificing the efficiency of the project’s operation and subsequent evaluation. However, the framework does not require adherence to the benchmarks, or the specific, quantifiable goals mandated by the project methodology. This could be a cause for concern, as the project’s goal may not be aligned with the framework.

The “Permanent”, “Measurable”, “Consistent”, “Traceable”, and “Legally & Financially Sustainable” principles have a fulfilment rate of less than 50%. This may possibly lead to a lack of confidence of how projects would stack up against others, and how viable it would be in the long term operationally and financially.

While the Gold Standard mandates that projects comply with existing policies and regulations, it does not necessitate considerations of potential changes to these rules in the future. Furthermore, the absence of a contingency plan if carbon credit revenue is exhausted could result in a scenario where there are insufficient resources for the project to operate continuously.

In comparison to the other two educated frameworks, the Gold Standard uniquely requires that registry information be made public for external verification when necessary. However, the framework does not mandate the use of the registry, placing it in a contradictory position. If the registry is not used, there is no effective mechanism to enforce the requirement about public access to the information.

The Gold Standard also requires the methodology used for measurement to be clearly stated. However, the requirement regarding the process for obtaining sampling data is missing. This could potentially result in a situation where although the methods of measurement are consistent across projects of the same type, the sampling data used for the measurements may not be comparable, which would render the projects incomparable.

4.5 Differences Among Frameworks

While the three frameworks evaluated share the aim to promote integrity and quality assurance in generating carbon credits, they differ significantly in terms of requirements, approved methodologies, and the emphasis each places on complying with both current and future regulations and policies. Based on the requirements identified in this whitepaper, we evaluate the differences between the three frameworks and offer insights into the consequences of these differences.

All three frameworks require documentation of how emissions are measured and the accompanying beneficial project outcomes. However, there are varying degrees of strictness in how detailed this documentation must be. All frameworks currently require projects to document the evidence of intended benefits, but only ACR and Verra's VCS specify that the documentation must be sufficiently thorough for replication and external review. ACR also outlines what must be included in this documentation, such as the measurement methodology, but VCS does not provide such details.

Under the "Additional" principle, although the three standards define what is considered as beyond Business-as-Usual to justify additionality, they differ on the required scientific rigour to substantiate both baseline determination and any resulting "additionality" benefits. This requirement exists in both the ACR and Gold Standard frameworks but not within Verra's VCS. Without this requirement, comparing projects in terms of additionality becomes difficult, as different approaches may be used to establish baselines and determine what constitutes "additional" benefits.

One of the most striking differences among the frameworks is the requirement for unique serial numbers to be assigned to each issued credit. ACR and Verra's VCS mandate that each carbon credit must be linked to a unique serial number. This ensures that every credit is traceable and accounted for, reducing the risk of double-counting, over-issuance, or non-retirement. In contrast, the Gold Standard does not explicitly require credits to be tagged with a unique serial number in its standard. This

could potentially increase the risk of oversight or manipulation in credits issued under the Gold Standard framework.

The ACR is the only framework that mandates the use of commonly accepted sampling methodologies for measuring emissions data, ensuring consistency and reliability. As a result, projects evaluated by Verra's VCS and Gold Standard may be more difficult to evaluate against their peers due to inconsistencies in data collection methods. Additionally, the Gold Standard framework also lacks a requirement for declaring a maximum permissible error in the collected emissions data.

Gold Standard also does not mandate that Verification and Validation Bodies (VVBs) be accredited, which could raise concerns about the objectivity and credibility of project assessments. Project owners might intentionally choose VVBs that deliver favourable outcomes. In contrast, both ACR and Verra's VCS require VVBs to meet specific accreditation standards.

4.6 Commonality Among Frameworks

As previously discussed, all three frameworks have different requirements, with some frameworks imposing more extensive and stringent requirements than others. However, ACR, Verra's VCS, and the Gold Standard also share certain commonalities in their requirements. This chapter discusses both the similarities among the frameworks, including areas that none of the frameworks addresses.

During the evaluation of the carbon crediting frameworks, two pillars – the Climate Impact Pillar and the Feasibility Pillar – stood out for the similarities across all three frameworks. The two principles, “Real” and “Permanent”, housed under the Climate Impact Pillar are highly correlated. In 7 out of the 9 scenarios analysed in this study, the two principles tend to act together. This would suggest that if a framework meets the passing criteria for one principle, it likely meets the passing criteria for the other as well. In other word, if a framework is evaluated as satisfying the “Real” principle, it is likely to also satisfy the “Permanent” principle.

On the other end, the Feasibility pillar and its associated principle, “Legally & Financially Sustainable”, reveal a low fulfilment rate across all evaluations. This indicates a general lack of emphasis on the financial, operational, and regulatory viability of the projects. Although the frameworks receive unsatisfactory scores for this pillar, all frameworks incorporate the requirement to consider revenue from the sale of carbon credits generated by the evaluated project. Discussions about the long-term sustainability of the project and its intended benefits when the revenue from carbon credits is depleted is also mandated. Therefore, financial sustainability is viewed as a relevant consideration in all three frameworks. However, the fact that most of the feasibility requirements are unmet indicates that the frameworks may struggle to ensure the long-term viability of the evaluated projects in achieving their intended outcomes.

A key similarity across the frameworks is the requirement to consider non-permanence risk during the calculation of emission reductions and targets. By including non-permanence risk in emissions calculations and goals, a more realistic long-term impact of the project can be managed. This is essential to ensure the quality of carbon credits and that the appropriate number of credits is issued to each project. However, only Verra's VCS provides detailed guidelines on how buffer credits should be calculated and set aside to address the non-permanence risk.

Although non-permanence risk is addressed in all three frameworks, none of the frameworks requires projects to specify which factors should be considered, such as reversal and leakage. This omission could lead to inconsistencies in interpreting emissions data, which may be inaccurate due to the use of factors that do not align with industry standards or the complete absence of these factors. In addition, consequences on how the removal or reduction of carbon would possibly affect other projects or communities may also be neglected.

All three frameworks require a clear discussion of how technological practices, if used, enhance the accuracy of emissions data. Additionally, both Verra's VCS and the ACR go a step further by mandating a discussion of the potential risks of technology failures that could inadvertently result in inaccurate emission readings. In addition, materiality thresholds are mandated by all three frameworks ensuring that minor inaccuracies do not significantly affect the overall emissions data reported. These measures further improve the precision of the emissions data measured and reported.

However, the ACR, Verra's VCS, and the Gold Standard do not require timelines for when project milestones should be achieved. Additionally, none of the frameworks mandates adherence to benchmarks or specific, quantifiable goals outlined in the project methodology. They also do not require consideration of steps to eliminate bias from the inputs. The absence of such requirements makes it difficult to compare and track a project's implementation progress, potentially leading to benefits being over (or under) reported.

5 Conclusion

Key Takeaways:

- Certain requirements, although residing within the frameworks, are still in their infancy and require further development.
- The frameworks place a stronger emphasis on pre-project verification and short-term value, but less consideration for long-term value in terms of project integrity and benefits.
- 80% of the requirements proposed in this paper have been met or partially met by at least one of the three frameworks evaluated, highlighting the critical need for an integrated framework.
- Substantial gaps still exist within the existing standards (which constitute 92% of the of issued carbon credits in the market) impeding the generation of high-quality carbon credits.

It is evident that certain pillars and principles have been addressed more carefully in the existing framework. The American carbon Registry is the most robust in assuring buyers that that carbon credits issued under the framework are of high quality. However, given the gaps that still exist within all three frameworks, significant reforms are needed to ensure that carbon credit participants can be confident that the carbon credits issued under these frameworks are of high quality.

Based on this analysis we call for the development of an integrated framework that incorporates the current best practices of existing frameworks, as well as the critical principles and requirements promulgated in this study.

This integrated framework is critical for the carbon markets to contribute to global decarbonisation efforts.

6 References

- [1] K. J. W. Li Hongyan, "The Growth of Voluntary Carbon Markets and Challenges for Further Development," 29 March 2024.
- [2] World Bank Group, "Global Carbon Pricing Revenues Top a Record \$100 Billion," 21 May 2024. [Online]. Available: <https://www.worldbank.org/en/news/press-release/2024/05/21/global-carbon-pricing-revenues-top-a-record-100-billion>. [Accessed 31 August 2024].
- [3] Carbon Offset Guide, "What is a Carbon Credit?," [Online]. Available: <https://offsetguide.org/understanding-carbon-offsets/what-is-a-carbon-offset/>. [Accessed 30 September 2024].
- [4] C. L. P. M. Christopher Blaufelder, "McKinsey Sustainability," 29 January 2021. [Online]. Available: <https://www.mckinsey.com/capabilities/sustainability/our-insights/a-blueprint-for-scaling-voluntary-carbon-markets-to-meet-the-climate-challenge>. [Accessed 10 October 2024].
- [5] V. S. Silvia Favasuli, 10 June 2021. [Online]. Available: <https://www.spglobal.com/commodityinsights/en/market-insights/blogs/energy-transition/061021-voluntary-carbon-markets-pricing-participants-trading-corsia-credits>. [Accessed 22 October 2024].
- [6] M. Z. Brendan Player, "Stantec," September 2024. [Online]. Available: <https://www.stantec.com/content/dam/stantec/files/PDFAssets/white-papers/high-quality-carbon-credits-whitepaper.pdf>. [Accessed 14 October 2024].
- [7] The American Carbon Registry, "The ACR Standard Version 8.0," July 2023.
- [8] The Gold Standard, "Gold Standard For The Global Goals, Principles & Requirements, Version 1.2," October 2019.
- [9] Global Carbon Council, "Project Standard V4.0," 2023.
- [10] Verra, "VCS Standard V4.7," April 2024.
- [11] Verra, "Verified Carbon Standard," [Online]. Available: <https://registry.terra.org/app/search/VCS/All%20Projects>. [Accessed 15 October 2024].
- [12] The Gold Standard, "GSF Registry," [Online]. Available: <https://registry.goldstandard.org/credit-blocks/issuances?q=&page=1>. [Accessed 15 October 2024].
- [13] ACR, "ACR," [Online]. Available: <https://acr2.apx.com/myModule/rpt/myrpt.asp?r=111>. [Accessed 15 October 2024].
- [14] S. S., "CarbonCredits," 30 April 2024. [Online]. Available: <https://carboncredits.com/verras-vcs-program-update-navigating-corsia-and-icvcm-alignment/>. [Accessed 1 November 2024].
- [15] P. Greenfield, "The Guardian," 18 January 2023. [Online]. Available: <https://www.theguardian.com/environment/2023/jan/18/revealed-forest-carbon-offsets-biggest-provider-worthless-verra-aoe>. [Accessed 26 September 2024].
- [16] ACR, "ACR Carbon," [Online]. Available: <https://acrcarbon.org/about-us/>. [Accessed 15 October 2024].
- [17] American Carbon registry, "Winrock," [Online]. Available: <https://winrock.org/wp-content/uploads/2017/01/Winrock-ACR-Handout1.pdf>. [Accessed 2024 October 10].

- [18] The American Carbon Registry, "Methodology For The Quantification, Monitoring, Reporting and Verification of Greenhouse Gas Emission Reductions and Removals from Improved Forest Management on Non-Federal US Forestlands Version 2.1," July 2024.
- [19] The American Carbon Registry, "Methodology For The Quantification, Monitoring, Reporting and Verification of Greenhouse Gas Emissions Reductions and Removals From Improved Forest Management on Canadian Forestlands Version 1.0," September 2021.
- [20] Carbonibus, "Carbonibus," 5 July 2023. [Online]. Available: <https://www.carbonibus.org/post/verra-vcs-vs-gold-standard-comparing-carbon-credit-standards>. [Accessed 14 October 2024].
- [21] Hugging Face, "nboard/ESG-BERT," [Online]. Available: <https://huggingface.co/nboard/ESG-BERT>. [Accessed 21 October 2024].
- [22] G. H. Laurens van der Maaten, "Visualizing Data using t-SNE," *Journal of Machine Learning Research*, vol. 9, pp. 2579 - 2605, 2008.
- [23] United Nations, "Take Urgent Action to Combat Climate Change and its Impacts," [Online]. Available: <https://unstats.un.org/sdgs/report/2021/goal-13/>. [Accessed 2 October 2024].
- [24] S. H, "Demand for Carbon Credits Could Increase +15X by 2030 and 100X by 2050," 29 July 2021. [Online]. Available: <https://carboncredits.com/demand-for-carbon-credits-could-increase-15x-by-2030-and-100x-by-2050/>. [Accessed 27 September 2024].

Appendix A

To analyse the correlation between the principles, clustering was performed on these sentences and later visualized. Below is the overview of the methodology used:

1. **Sentence Vectorisation:** A pre-trained language model, ESG-BERT, Ref [21] , is used to understand the meaning of each sentence. The model creates a numerical representation of each sentence that captures its meaning.
2. **Grouping Similar Sentences:** The sentences are then grouped based on how similar they are, using a clustering technique (KMeans). The number of groups is specified (e.g., 6 groups).
3. **Visualization:** To better understand these groupings, the code uses a technique called t-distributed Stochastic Neighbour Embedding (T-SNE), Ref [22], that reduces the complexity of the sentence representations, allowing them to be visualized in two dimensions. The visualization shows how sentences are distributed and grouped, with each point representing a sentence.
4. **Cluster Quality Score:** The quality of the grouping is measured using the "Silhouette score," which shows how well each sentence fits into its assigned group.

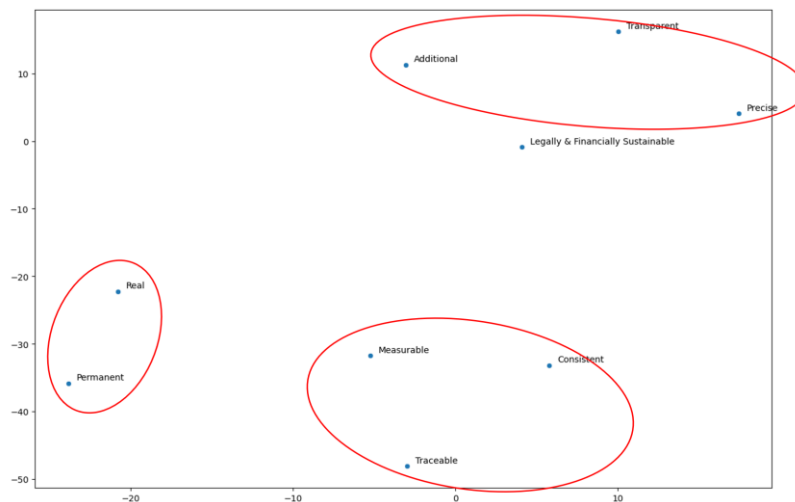


Figure A-1 - Results of Correlation Analysis

Appendix B

Principle	Requirement	Beneficial or Essential	Fulfilment		
			The American Carbon Registry	The Verified Carbon Standard	The Gold Standard
Additional	Require that the project's mitigation actions go beyond common practice	Beneficial	Y	Y	0.5Y
Additional	Require a clear description of at least one implementation barrier that will be overcome by the project	Beneficial	Y	Y	N
Additional	Require that the GHG emission reductions and/or removals generated by the project are materially above and beyond Business As Usual (BAU)	Essential	Y	Y	0.5Y
Additional	Specify a robust methodology that satisfies scientific requirements to determine the baseline data and the resulting additionality for the project.	Essential	Y	0.5Y	Y
Real	Require a detailed discussion of how the project's impacts will be verified through stakeholder confirmation.	Beneficial	N	N	N
Real	Require a clear timeframe and milestones of the project's planned progress.	Beneficial	N	N	N
Real	Require a clear description of how each milestone will be verified, including the description of technology and methods that will be used.	Beneficial	Y	N	Y

Principle	Requirement	Beneficial or Essential	Fulfilment		
			The American Carbon Registry	The Verified Carbon Standard	The Gold Standard
Real	Require that the GHG emission reductions and / or removals generated by the project are quantifiable and recorded accurately so that they are directly verifiable.	Essential	Y	Y	N
Real	Require that the measured effects are verified using a robust methodology that satisfies scientific requirements.	Essential	Y	Y	Y
Real	Provide a clear set of requirements regarding the documentation of evidence of the project's effects.	Essential	Y	Y	Y
Measurable	Prescribe a standard for the quality of the measurement equipment and the required (re)calibration frequency.	Beneficial	Y	Y	Y
Measurable	Require adherence to common practice for sampling methodology and statistical confidence	Beneficial	Y	N	N
Measurable	Require that the measured effects are recorded in accordance with applicable reporting requirements and performance standards, clearly documenting the data sources and methodology used for measurement.	Essential	0.5Y	Y	N
Measurable	State the maximum permissible errors allowed in the measurement of specific effects.	Essential	Y	Y	0.5Y
Measurable	Prescribe the acceptable timeframe and frequency of measurements of specific effects.	Essential	Y	N	N

Principle	Requirement	Beneficial or Essential	Fulfilment		
			The American Carbon Registry	The Verified Carbon Standard	The Gold Standard
Permanent	Provide a clear set of guidelines for the discussion of non-permanence risks as per project methodology approved by the framework	Beneficial	Y	Y	Y
Permanent	Require process of the deposit of credits into buffer pool to mitigate against risk to permanence to be laid out	Beneficial	N	Y	N
Permanent	Ensure that the project has a lasting and permanent effect on the reductions and/or removals of GHG	Essential	Y	Y	N
Permanent	Require that conservative and realistic assumptions are used in the framework methodology, accounting for various risk factors such as reversibility and leakage, regardless of intentionality.	Essential	Y	0.5Y	N
Permanent	Prescribe specific deadlines for project owners to state the minimum project term, the benefit horizon, and the start of the project's permanence period.	Essential	0.5Y	0.5Y	N
Transparent	Require the accreditation of the validation entity performing independent verification	Beneficial	Y	Y	N
Transparent	Require a clear description of the audit team, with specific roles and responsibilities of each team member	Beneficial	N	N	Y

Principle	Requirement	Beneficial or Essential	Fulfilment		
			The American Carbon Registry	The Verified Carbon Standard	The Gold Standard
Transparent	Require a clear description of the procedures that will be used to track the project's GHG emission reductions and/or removals, and how these are transferred to other parties aiming to meet their own targets.	Beneficial	N	Y	N
Transparent	Provide a clear set of guidelines for the discussion of measured and expected impacts within the verification report	Beneficial	N	0.5Y	N
Transparent	Require a clear and thorough documentation of the project (including its design, scope, and measurement methodology) to allow for replication and outside review	Essential	Y	Y	0
Transparent	Require independent framework setters, measurement and verification team, and project owners who have no conflict of interest with all other parties involved.	Essential	Y	N	Y
Transparent	Require adherence to the materiality threshold determined by the framework.	Essential	Y	Y	Y
Precise	Provide a clear set of guidelines for the discussion of the avoidance and/or elimination of potential biases in the quantification methodology of GHG emissions, including the use of site-specific emission factors and the inputs for the estimation of the measurement of baseline and future emissions.	Beneficial	N	N	N

Principle	Requirement	Beneficial or Essential	Fulfilment		
			The American Carbon Registry	The Verified Carbon Standard	The Gold Standard
Precise	Require a thorough documentation verifying the level of assurance required through documentation.	Beneficial	Y	Y	N
Precise	Require that any future deviations from the proposed program methodology approved by the framework does not reduce the conservativeness of the quantification of emission reductions or removals.	Beneficial	Y	Y	Y
Precise	Require a clear discussion of how the quantification methodology will leverage technological practices to enhance its accuracy, while also addressing the potential risks of technology failure in this context.	Beneficial	Y	Y	0.5Y
Precise	Require a clear discussion of the process undertaken to validate the accuracy of the measurement of the project's effects. For example, requiring that the emission factors used in the measurements are derived from a scientific peer-reviewed sources, are appropriate for the specific GHG emitter, and account for any potential uncertainty.	Essential	Y	N	N
Precise	Prescribe a minimum materiality threshold	Essential	Y	Y	Y
Precise	Require adherence to the benchmarks, specific and quantifiable goals that are required by the approved methodology.	Essential	N	N	N

Principle	Requirement	Beneficial or Essential	Fulfilment		
			The American Carbon Registry	The Verified Carbon Standard	The Gold Standard
Precise	Require a validation of the measured effects of the project using methodologies evaluated and approved by the framework setter.	Essential	Y	N	Y
Consistent	Require high-quality sources of information and comparison for data with high levels of uncertainty to elicit a greater confidence on the assurance process.	Beneficial	N	Y	0.5Y
Consistent	Require existing projects to update their PDDs when any changes to the Standard/Methodology are made.	Beneficial	0.5Y	N	N
Consistent	Require a consistent methodology that can be applied across all projects within the same project type	Essential	0.5Y	N	N
Consistent	Require measurements and data sampling of similar variables to be conducted consistently to enable easy comparison across assessed projects.	Essential	0.5Y	Y	N
Consistent	Require a clear description of the methodology used for measurement. Methodology is to be made publicly available to ensure consistency amongst all projects evaluated under the framework.	Essential	Y	0.5Y	Y
Traceable	Promote coordination among registries to ensure that a specific project (or activity) is not registered with more than one registry.	Beneficial	N	N	N
Traceable	Issue a unique serial number to each unit of carbon credit issued.	Essential	Y	Y	N

Principle	Requirement	Beneficial or Essential	Fulfilment		
			The American Carbon Registry	The Verified Carbon Standard	The Gold Standard
Traceable	Prescribe the use of a reputable carbon registry to track the issuance, ownership, and retirement and/or cancellation of carbon credits.	Essential	N	N	N
Traceable	Require availability and public access to the carbon registry information so that the credits are verifiable with other registries.	Essential	Y	Y	Y
Legally & Financially Sustainable	Require a detailed contingency plan to address potential changes in regulations or governmental structures	Beneficial	N	N	N
Legally & Financially Sustainable	Require a discussion of potential situations where targeted GHG emissions reductions or removals are not met, and the proposed viable mechanisms to address these situations.	Beneficial	N	N	N
Legally & Financially Sustainable	Promote publicly accessible mechanisms to track and evaluate the performance and success rate of project owners in ongoing and completed GHG emission reduction/removal projects	Beneficial	N	N	N
Legally & Financially Sustainable	Require a thorough discussion regarding viability and self-sufficiency of the project, particularly once the project initial funding runs out and / or carbon related revenues (e.g. carbon credits) are absent. Consider the absence of carbon revenues for project viability and determine if projects are self-sufficient once initial funding is used	Essential	Y	Y	Y

Principle	Requirement	Beneficial or Essential	Fulfilment		
			The American Carbon Registry	The Verified Carbon Standard	The Gold Standard
Legally & Financially Sustainable	Require a thorough assessment of whether the proceeds from the carbon credits (e.g., subsidies and carbon market potentials) associated with the project's location jurisdiction, can cover the costs of the proposed mitigation actions.	Essential	N	N	N
Legally & Financially Sustainable	Require a contingency plan if the resulting revenues from carbon credits, subsidies, and tax incentives, are not sufficient to cover the proposed mitigation actions.	Essential	N	N	N
Legally & Financially Sustainable	Require that the project owners have (1) complied with all current policies and regulations and (2) considered potential future changes in policies and regulations.	Essential	N	Y	0.5Y

Appendix C

Document Name	Document URL	Last Accessed
American Carbon Registry, The ACR Standard, Requirements and specifications for the quantification, monitoring, reporting, verification, and registration of project-based GHG emissions reductions and removals, Version 8.0, July 2023	Link	21 October 2024
American Carbon Registry, ACR Validation and verification standard, Version 1.1, May 2018	Link	21 October 2024
American Carbon Registry, Methodology for quantification, monitoring, reporting and verification of greenhouse gas emission reductions and removals from improved forest management on non-federal U.S. forestlands, Version 2.1 July 2024	Link	21 October 2024
American Carbon Registry, Methodology for quantification, monitoring, reporting and verification of greenhouse gas emission reductions and removals from improved forest management on Canadian forestlands, Version 1.0, September 2021	Link	21 October 2024
Verified Carbon Standard, VCS Standard, Version 4.7, 16 April 2024	Link	21 October 2024
Verified Carbon Standard, Methodology Requirements, Version 4.4, 4 October 2023	Link	21 October 2024
Verified Carbon Standard, Tool for the demonstration and assessment for additionality in VCS agriculture, forestry and other land use (AFOLU) project activities, Version 3.0, 1 February 2012	Link	21 October 2024
Verified Carbon Standard, Program Guide, 29 August 2023, Version 4.4	Link	21 October 2024
Gold Standard, Validation and verification standard, Version 1.0, 6 March 2023	Link	21 October 2024
Gold Standard, Principles & requirements, Version 1.2, October 2019	Link	21 October 2024
Gold Standard, Programme of activity requirements and procedures, Version 2.1, 5 October 2023	Link	21 October 2024
Gold Standard, Stakeholder consultation and engagement requirements, Version 2.1, 14 June 2022	Link	21 October 2024
Gold Standard, Simplified methodology for clean and efficient cookstoves, Version 3.0, 8 July 2022	Link	21 October 2024
Gold Standard, Safeguarding principles & requirements, Version 2.1, 29 June 2023	Link	21 October 2024