Research paper

The Role of Carbon Markets

How to ensure the design and delivery of high-quality and high-impact biogas carbon emissions reduction projects

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Cover: *Sistema.bio*

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List of abbreviations

CCP	Core Carbon Principle
CDM	Clean Development Mechanism
COP	Conference of Parties
ESG	Environmental, Social and Governance
EU ETS	European Union Emissions Trading System
FCDO	UK Foreign Commonwealth and Development Office
fNRB	Fraction of Non-renewable Biomass
GHG	Greenhouse Gas
HFC	Hydrofluorocarbon
IC-VCM	Integrity Council for Voluntary Carbon Markets
IPCC	Intergovernmental Panel on Climate Change
ITMO	Internationally Transferred Mitigation Outcome
IUCN	International Union for Conservation of Nature
KPT	Kitchen Performance Tests
LDC	Least Developed Country
LPG	Liquefied Petroleum Gas
MoFuSS	Modelling Fuelwood Savings Scenarios
MRV	Monitoring, Verification and Reporting
NGO	Non-governmental Organisation
PM	Particulate Matter
PV	Photovoltaic
SDGs	Sustainable Development Goals
SME	Small and Medium Enterprises
tCO2e	Tonne of Carbon Dioxide-Equivalent
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
VVB	Validation and Verification Body
WWF	Worldwide Fund for Nature

Executive Summary

Biogas is a source of renewable energy that allows farmers to turn organic waste from their livestock into a valuable resource. **Sistema.bio**, a company founded in 2010, has an extensive track record in the manufacturing, installation, and after-service of these biogas digester units. The company uses carbon finance to subsidise the end price of the units to farmers, making the product more accessible.

This report commissioned by Sistema.bio and Shell Foundation with funding from the Foreign Commonwealth and Development Office (FCDO) outlines the factors that make a high-quality and high-impact carbon emissions reduction project, with a specific focus on biogas technology. The research is based on the premise that to scale carbon finance and channel funds to drive biogas technology into rural and low-income households, the underlying integrity of carbon projects must be high. We hope this paper will be useful for other actors in this space, including technology providers, project developers, investors, carbon credit buyers and governments in their work to make clean cooking technologies more widely accessible.

The report will answer the following **two research questions**, drawing from current market initiatives and scientific literature:

1. What are the key characteristics of high-quality emissions reduction projects for the biogas sector that ensure long-term results?
2. What are the specific risks associated with developing, financing and delivering emissions reductions from rural clean energy / clean cooking projects (biogas focus) to voluntary and compliance markets, and how do those risks affect different actors in the ecosystem differently (i.e., developers, technology providers, investors, emissions reduction off-takers, farmers, and governments)?

With regards to the first research question, the authors identify **three main characteristics that a project needs to have to be considered "high quality and high impact."**

First, independent of the carbon component, the project **must generate value to the end user of the technology**, thereby contributing to the sustainable development of rural communities. Moreover, the relationship between the project developer and technology provider with the customer should be of a **responsible and ethical nature** and the project should **minimise and mitigate the negative effects it has on humans or the environment** to the best extent possible. Biogas technology and Sistema.bio's carbon projects meet these requirements as the digester contributes to several Sustainable Development Goals (SDGs), creating substantial socio-economic benefits over the course of its lifetime. Being a social company, Sistema.bio engages with farmers on an equal footing and fairly shares the carbon benefits with its users, while also having in place a few safeguarding procedures to avoid negative or unintended consequences.

Second, **both the environmental and social impact of the project must be calculated and communicated accurately to the public**. This report provides an assessment of four technical requirements imposed by carbon markets and discusses them within the context of current initiatives. The first requirement is the concept of **additionality** which seeks to ensure that the generated emissions reductions can be attributed directly to the carbon finance; this is commonly the case for household biodigester systems. The second requirement is **permanence** which deals with the risks of reversals. This is however less applicable to the biogas context. The third requirement is **robust quantification of emission reductions and removals** which examines both baseline setting and monitoring procedures. The former especially has been subject to extensive scrutiny, and the report outlines three components that make up a credible baseline: **1**) the fraction of non-renewable biomass, **2**) baseline fuel consumption, and **3**) emissions factors. Regarding monitoring procedures, the report outlines the different options that are available to project developers and explains why Sistema.bio's approach of relying on a mixture of surveys, multi-day in-field testing, and sensor allows it to obtain accurate results on usage patterns of the stove and digester. The fourth requirement covered to accurately represent the project impact is the **avoidance of double counting**. After all, only one actor can credibly claim to have generated the impact.

Finally, a project needs to obtain **external certification** to be considered high quality and high impact. Project developers should rely on a reputable carbon standard for the certification of the impact and have the claims corroborated by an independent auditor.

The second part of the report focuses on **carbon project risks and how these can be mitigated**. The most employed commercial structure by Sistema.bio is introduced, explaining how the carbon finance is channelled to farmers and how the company mitigates the risks in its carbon projects.

The report identifies the following **risk categories**: **1**) implementation; **2**) registration, validation and certification; **3**) performance; **4**) verification and issuance; **5**) delivery; and **6**) reputational. An analysis of these risk categories shows that Sistema.bio is able to absorb a lot of risk for investors but is also able to shield farmers from any project-related risks, as they receive the full carbon revenues upfront via the subsidy of the digester. The risks that remain to both investors and carbon credit buyers are of a volumetric nature, as delays in the implementation or adoption of the digesters would result in less carbon credits. Conservative projections during the initial modelling phase can mitigate these risks efficiently. Sistema.bio has a long track record in implementing energy access projects in complex socio-economic environments.

Introduction

Sistema.bio was founded in 2010 on three powerful ideas: **1)** Biodigester technology has a deep impact on the health, well-being and productivity of smallholder farmers; **2)** Biodigester technology can reduce significant methane and carbon dioxide (CO2) emissions from farmers, which can be measured and turned into carbon credits under the Clean Development Mechanism (CDM); and **3)** The carbon market can fund the development and roll-out of significant quantities of biodigesters for farmers around the world.

When the company was founded, early carbon markets were in their heyday. Prices for carbon credits under the United Nations (UN) framework were as high as USD $20 per tonne, leading the company's co-founders to consider carbon revenues as a major driver in the growth of biogas technology. However, by the time the digesters went into serial production, the world had undergone a global recession and demand for carbon credits had reduced heavily due to changes in the European Union (EU) regulatory framework. Carbon credits fell to less than USD $1 per tonne and carbon markets were not a viable funding source for biodigester projects.

Over a decade later, the data remains clear: climate change is creating threats to global ecosystems, food systems, and communities, and the world requires a focus on solutions that support the mitigation and adaptation to climate change as quickly as possible. There are many approaches to reducing greenhouse gas emissions, capturing carbon from the atmosphere, and adapting to the worst impacts of climate change. These include government regulation and taxes, international trade agreements, private initiatives, and carbon markets. Carbon markets stand out as a proven mechanism for funding projects and initiatives that can reduce carbon emissions. In some cases, carbon markets can incentivise technological development which reduces current and future emissions while also supporting adaptation to climate change. For carbon markets to grow and deliver impact at scale, standards, transparency, and trust need to grow at all stages of the project development process. Risks need to be clearly understood and mitigated.

Based on the current state of carbon markets, this paper focuses on how efforts to set standards by which to measure biogas carbon emissions reduction projects can improve the global confidence and function of carbon markets and ensure the design and delivery of high-quality and high-impact projects. We hope this paper will be useful for other actors in this space, including technology providers, project developers, investors, carbon credit buyers and governments in their work to make clean cooking technologies more widely accessible.

Drawing from current market initiatives and scientific literature, this paper will answer the following research questions:

1. What are the key characteristics of high-quality emissions reduction projects for the biogas sector that ensure long term results?
2. What are the specific risks associated with developing, financing and delivering emissions reductions from rural clean energy / clean cooking projects (biogas focus) to voluntary and compliance markets, and how do those risks affect different actors in the ecosystem differently (i.e., developers, technology providers, investors, emissions reduction off-takers, farmers and governments)?

Below, the report provides a short overview of Sistema.bio, and its biogas technology. **Part 1** examines the different attributes required to be considered a "high-quality and high-impact" carbon project. The section is broken down into three subsections that discuss what constitutes a high-quality project, how the impact of a carbon project can be quantified accurately, and the role of external certification bodies. **Part 2** provides an overview of the potential commercial structure to enable carbon projects and discusses various risks associated with them, how these affect the actors involved, and how they can be mitigated. The report concludes by summarising the lessons learnt about delivering high-quality and high-impact carbon projects in Sistema.bio's experience.

Carbon markets

"Carbon market" is an umbrella term that refers to several different market-based mechanisms. The central "currency" of these markets is the "carbon credit," a term referring to a metric tonne of CO2 equivalent (based on a relative heating value over a period of time) that is not in the atmosphere

because it has either been reduced or captured. While all these instruments have the same underlying purposes of mitigating climate change, they differ profoundly in design.

On one end of the spectrum are **compliance market**s such as the European Union Emissions Trading System (EU ETS). These are regulated by a public body, which sets limits on emissions over a certain period of time. On the other end of the spectrum are **Voluntary Carbon Markets (VCMs)**. The VCM comprises several private carbon crediting schemes that enable private actors and corporations to generate, purchase and sell carbon credits. It is considered "voluntary" because it generally falls outside any regulated (i.e compliance) instruments. The best-known examples for such crediting schemes are the Gold Standard for Global Goals and Verra's Verified Carbon Standard. Demand is mainly driven by companies that purchase these carbon credits to fund climate action or make sustainability-related claims. The latter has come under increasing scrutiny, and several initiatives have emerged to standardise what claims can be made when purchasing carbon credits.

Somewhere in the middle of this spectrum is **Article 6 of the Paris Agreement** which contains two market-based mechanisms. Article 6(2) is of a decentralised nature, providing a framework for the transferal of mitigation outcomes (such as emission reductions) from one country to another. It leaves space for the cooperating countries to decide on the exact nature of the units, requirements, and procedures, but ensures that whenever a mitigation outcome is traded (referred to as an "ITMO", or internationally transferred mitigation outcome), only one country can claim the underlying emission reduction. In other words, it constitutes an accounting mechanism to avoid double counting. Switzerland is an example of a country that has engaged in this mechanism for several years already and has signed over a dozen bilateral agreements with countries, ranging from Ghana and Peru, to Thailand and Vanuatu. Article 6(4) is a centralised carbon registry that is more similar in its functioning to the CDM, or Gold Standard. It will have its own rules and requirements, which are currently still being finalised by the Subsidiary Body. No agreement was reached at the Conference of the Parties (COP) 28, leaving the final decisions to be adopted at the next COP in late 2024. Because Article 6(4) is not operational yet, private sector participation in Article 6 is currently only possible via Article 6(2).

Taken together, the VCM includes a range of market-based mechanisms that vary greatly in terms of market participants, involvement of public bodies and size. Lack of uniform standards and rules across the market, especially in the context of voluntary carbon markets has led criticism and calls for reformation of the market. The argument points out that these markets will only be able to reach their full potential if buyers are confident in the integrity of the market, and the quality of the carbon credits. The following section will examine some of these initiatives.

Sistema.bio: creating value from waste

Sistema.bio is a social enterprise that works to reduce poverty, increase global food security, and reduce impacts of climate change. It works directly with smallholder farmers to improve their efficiency, productivity, and long-term environmental sustainability by providing access to innovative biodigester technology, training, service, and financing. With Sistema.bio's biodigester, farmers turn their organic waste into clean energy and organic fertiliser, grow more and better food, save money, and produce less emissions.

By the end of 2023, Sistema.bio had delivered over 100,000 energy access projects around the world, and has been recognised by the World Economic Forum, the Ashden Awards, Energy for All, and the Clean Cooking Alliance as a leader in energy access. Its four regional hubs are located in Mexico, Colombia, India and Kenya and support partnerships and operations in over 30 countries around the world.

The products and services of Sistema.bio have been shown to have an impact on farmers in reducing carbon emissions and significant co-benefits measured within the SDG framework. Previous research done by Sistema.bio has shown how results-based financing can support the development of biodigester systems for farmers and where the carbon markets fit within that goal. This report builds on this work.

Sistema.bio's biogas technology

Sistema.bio's pre-fabricated biodigester can be installed easily and provides a comprehensive system for farmers to process the daily waste of a farm and livestock to produce biogas that can be used for clean cooking and thermal processes. The output of the digester is a powerful biofertiliser which is stored and applied in the fields as a substitute to chemical fertilisers. The various components of the Sistema.bio reactor can be seen in **Figure 1** below.

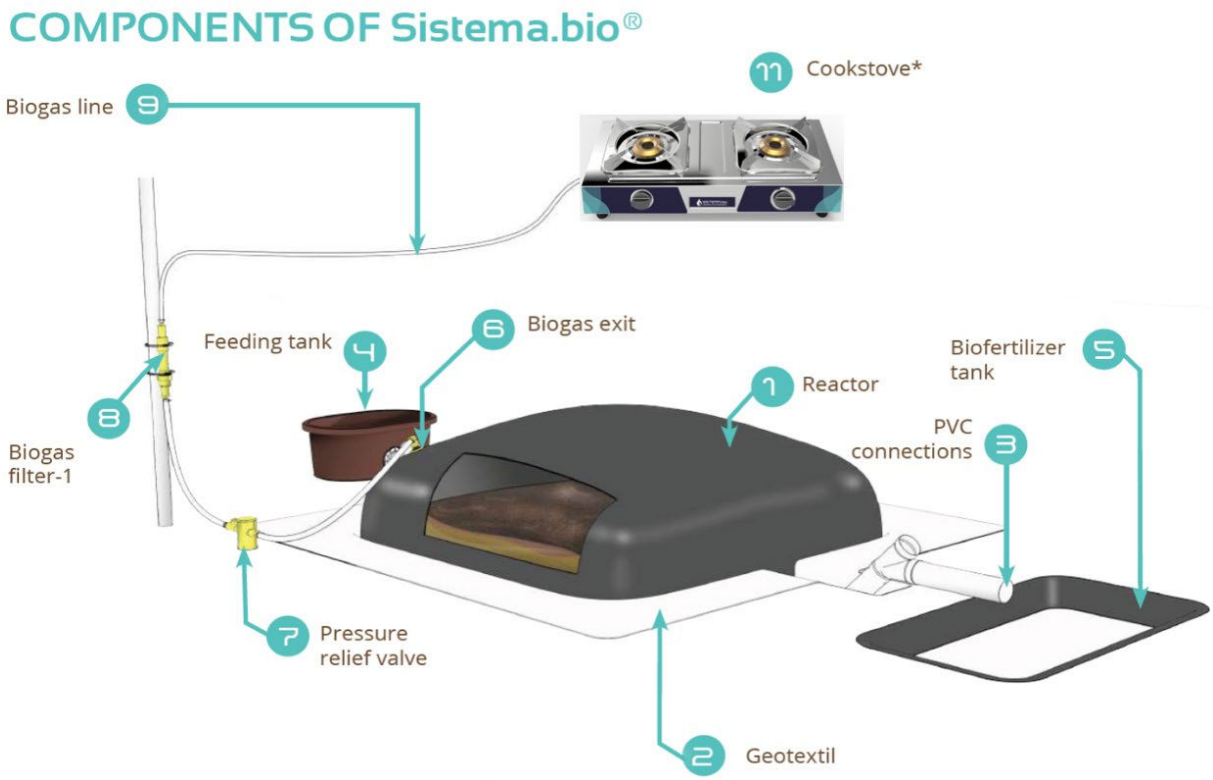

Figure 1: Sistema.bio's biodigester displaying its components and main features

Together with the technology package, a proven implementation methodology guides the farmers in the identification, installation, training, and on-going monitoring and reporting of issues. Adherence to strict planning, implementation, and reporting is as important as the quality of the technology to ensure the success of the project in delivering high-quality emissions reductions. Specific processes, a specialised data platform, certifications and many points of quality control provided by Sistema.bio ensure the high adoption rates and impact from each project. **Figure 2** illustrates Sistema.bio's customer journey.

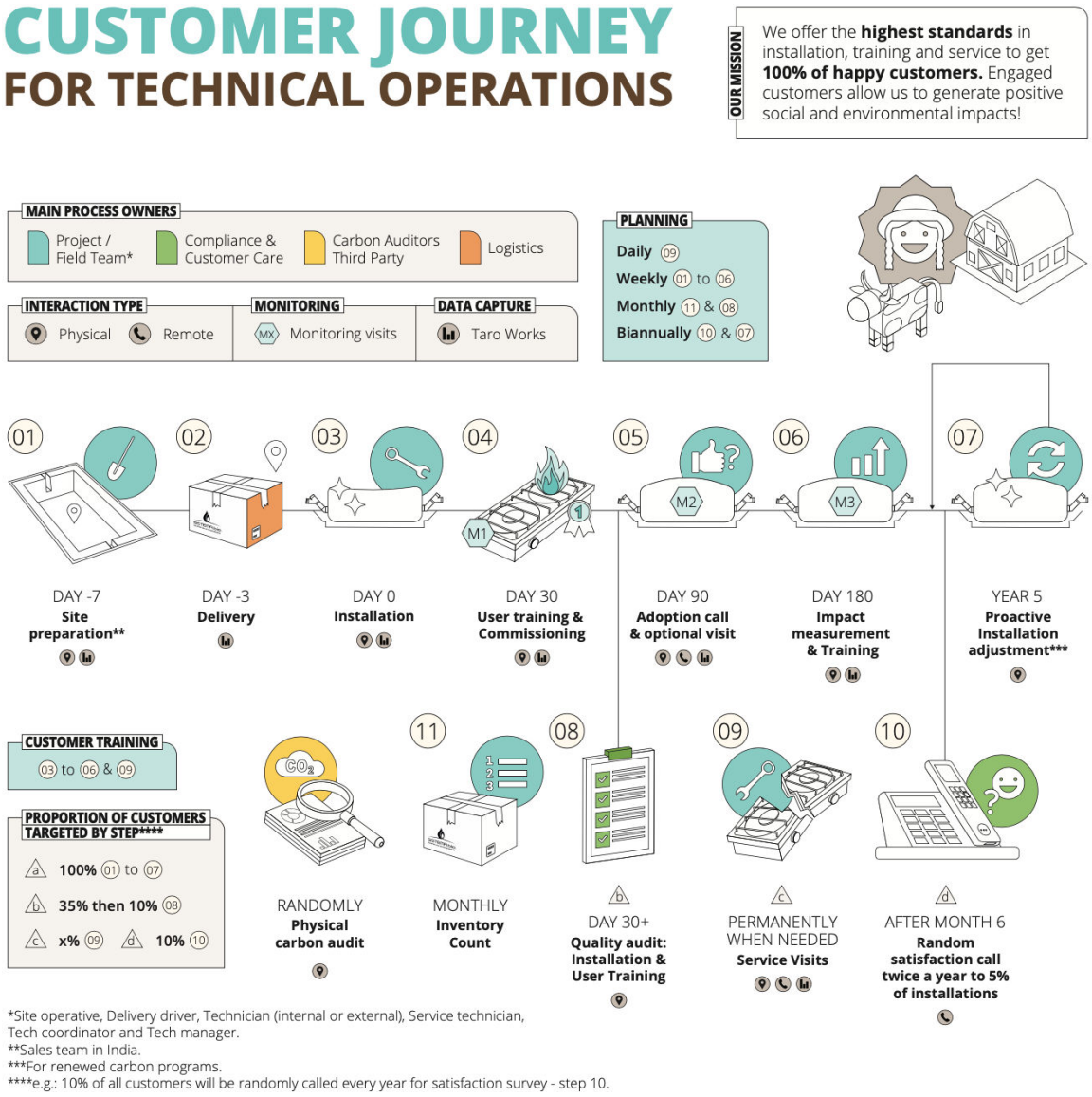

Figure 2: The Sistema.bio's customer journey

The core market segment of Sistema.bio are small-scale farmers who own livestock (2+ cows) and medium-scale commercial farmers (owning up to 200 cows) who cannot afford industrial-scale biodigester systems. Both groups are found primarily in rural areas, where incomes are often low, access to traditional energy sources is problematic or costly, and the environmental impacts of fossil fuel use are severe. Above 75% of end users are women, as they are in charge of domestic care and farming activities. As a result, they are the most affected by the harmful effects of emissions when using firewood as the main source of energy, mainly for cooking or other productive uses in the farm (i.e., boiling water for milking machines cleaning processes).

Part 1: What Makes a High-Quality Carbon Credit to Drive Healthy Carbon Markets?

Various initiatives have emerged over the past years with the objective of consolidating best practices and providing guidance to stakeholders such as project developers, buyers of carbon credits, and non-governmental organisations (NGOs) around what makes a high-quality and high-impact carbon project. In general, initiatives can be classified into two categories: **1) supply-side initiatives** that mainly deal with the integrity of the carbon credits themselves, and **2) demand-side initiatives** which focus on their use and the external communication surrounding it. For this paper, the focus is on the supply side, since that is where Sistema.bio is primarily engaged in.

While in general all these initiatives vary in scope and are structured differently, they ultimately **evaluate carbon projects over three key dimensions.**

1. **The project needs to be impactful;** that is, it should create long-lasting impact, value for the beneficiaries, and not cause any harm to humans or the environment.
2. **The social and environmental impacts of the project must be represented conservatively and accurately**.
3. **The project must be listed on a public registry and vetted by an independent third party.**

The following sections will examine these requirements more closely, drawing on current initiatives and best practices.

What constitutes a high-impact carbon project?

Historically, the key concern for carbon markets has been to achieve decarbonisation at the lowest possible abatement costs. Under the Kyoto Protocol,[1] "developed countries" with strict climate targets could make use of so-called flexibility mechanisms, enabling them to achieve parts of their emissions targets at lower costs abroad. The underlying rationale was, therefore, primarily of an economic nature, with co-benefits and contribution towards sustainable development being less of a priority. A good example of this is the project category of hydrofluorocarbon (HFC)-23 destruction, which entailed the destruction of industrial gasses. While the costs of achieving these emission reductions were low, they did not generate any substantial co-benefits besides reducing greenhouse gas emissions. With the emergence of voluntary carbon markets, and demand from corporates who were purchasing carbon credits to bolster their environmental, social and governance (ESG) performance, co-benefits became increasingly important. In addition, the shift from the Kyoto Protocol to the Paris Agreement fundamentally transformed the purpose of carbon markets. These were no longer seen as a simple tool for developed countries to achieve their climate targets at lower costs, but instead as means of equal cooperation between countries to reduce emissions whilst also contributing towards sustainable development. As a result, merely reducing greenhouse gas emissions no longer suffices to qualify as a "high-quality project". Instead, **the project must meet several criteria, which can be categorised as follows:**

1. Create real impact and value to the users of the technology, and thus contribute to sustainable development.
2. Engage in a meaningful and responsible way with end users as project developer.
3. Ensure safeguards are in place to prevent any negative effects on humans or the environment.

Sistema.bio has an extensive track record in carbon markets. The first carbon project of Sistema.bio began its crediting period in 2018 and has since then issued nearly 70,000 Verified Emission Reductions under the Gold Standard registry.[2] While initially working with external consultants, this work has now been largely internalised with the building up of the Carbon & Impact team. Three additional projects in Uganda, India and Mexico have been successfully brought through the Gold Standard certification process by Sistema.bio directly. Projects in the pipeline include two more Gold Standard projects in India and Kenya, as well as a program under Article 6 of the Paris Agreement in

[1] The Kyoto Protocol was a legally binding agreement between 192 countries that was adopted in 1997. As the predecessor to the Paris Agreement, it set strict emissions reduction targets for industrialized countries and economies in transition. For more information see here: https://unfccc.int/kyoto_protocol.
[2] For more information on the Gold Standard registry, see: https://registry.goldstandard.org/projects/details/2198.

Malawi. This experience uniquely positions Sistema.bio within the carbon space for community service projects.

The following sections examine how Sistema.bio's biogas projects meet the above criteria.

Create real impact and value to the users of the technology, and thus contribute to sustainable development

Sistema.bio's technology creates impact for farmers in a number of ways (**Figure 3**). The core SDGs related to Sistema.bio's work are as follows:

- **SDG 13 - Climate Impact:** A biodigester can avoid between 6 to 150 tonnes of CO2-equivalent (tCO2e), depending on its capacity.
- **SDG 3 - Health:** A switch from cooking with firewood to using biogas has shown to reduce personal exposure to particulate matter (PM) 2.5 by 68%, effectively adding 21 days of healthy life to a household each year.[3]
- **SDG 5 - Gender Equality:** Using biodigesters can reduce the time spent collecting firewood and cooking with it, adding 285 hours (about 12 days) of Quality Time[4] for the female cook per household, per year.[5]
- **SDG 7 - Energy Access:** Biodigesters provide a source of clean, renewable, and affordable energy for households.

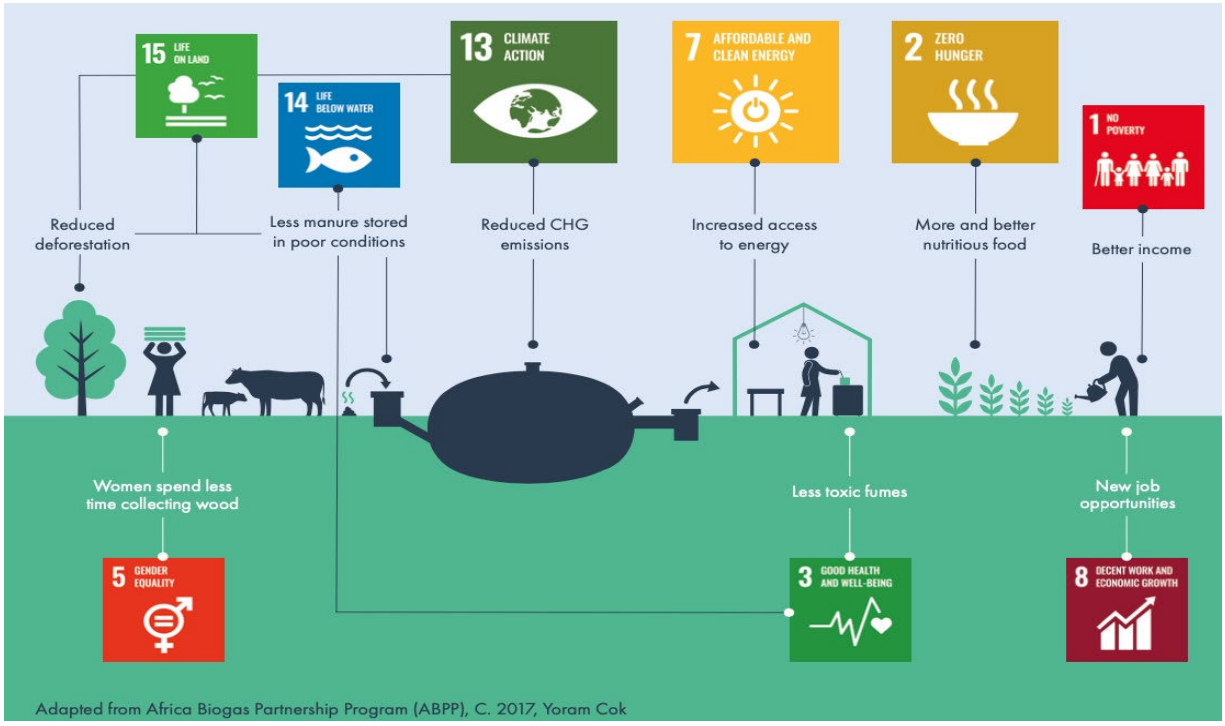

Figure 3: The various SDGs related to household biogas projects

In addition to these core co-benefits, Sistema.bio also helps farmers increase their overall productivity and provides a solution to on-site waste management. Prior to owning a digester, farmers depended on alternative waste management methods such as stacking or storing of the manure in pits or lagoons. Besides leading to methane emissions, these practices cause odours and attract flies,

[3] For more information see the report *Clean Impact Bond: Mobilizing Finance for Clean Cooking* by the International Finance Corporation, developed together with Sistema.bio and other partners: https://www.ifc.org/content/dam/ifc/doc/2023-delta/ifc-clean-impact-bond-052023.pdf

[4] Time cooks spend on productive tasks and/or rest and leisure.

[5] See the report referred to in footnote 2.

becoming a nuisance for farmers. The organic fertiliser that is produced by the digester can help farmers save costs on chemical fertilisers.

The outcomes of Sistema.bio's work on co-benefits have been corroborated by other research initiatives. According to a study commissioned by Gold Standard, biogas projects have on average the highest co-benefits out of all the project types.[6] This study also found that each tonne of CO2 that is reduced by a biogas project generates a socio-economic value of USD $465 (Figure 4). When putting that into perspective and considering that even the smallest Sistema.bio digester generally reduces above 50 tCO2e during its 10-year warranty phase, the contribution towards sustainable development becomes more than apparent.

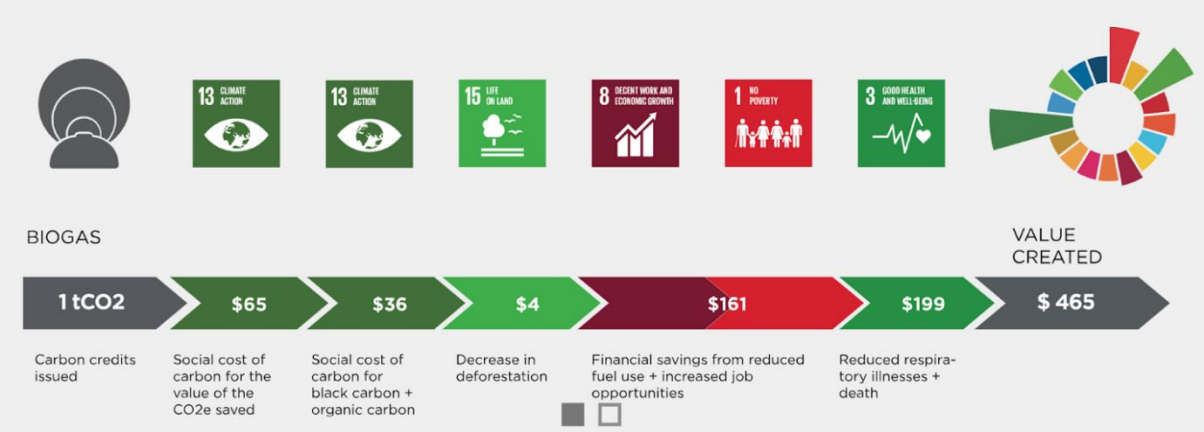

Figure 4: The socio-economic value of one tonne CO2-equivalent reduced by a biogas project[7]

Engage in a meaningful and responsible way with end users as project developer

Sistema.bio views the farmers it works with as the key agents of change, and thus as an integral part to its vision. In practice, this means that the installation of the digester is not the end, but rather the beginning of an extended relationship, where farmer feedback is encouraged and considered. In line with Gold Standard requirements and Cooking Alliance's *Interim Principles for Responsible Carbon Finance in Clean Cooking*, Sistema.bio engages users, farmer associations, NGOs, and public institutions during the design phase of the projects. Within this context, stakeholders are given the opportunity to ask questions or provide inputs. This process is documented and published on the Gold Standard registry upon listing. Moreover, most communication channels are kept open throughout the project lifetime, giving stakeholders not only the opportunity to provide inputs at the early stages of the design, but also thereafter.

All Sistema.bio customers that purchase a biogas system at a reduced price due to carbon finance are informed of this prior to their purchase. At the end of this process, farmers sign a carbon waiver, confirming the fact that they receive a digester at a discounted rate in exchange for the underlying environmental attributes. All Sistema.bio employees, especially technicians, are trained on carbon projects in general, as well as the operation of its own projects more specifically. This ensures that employees engaging with farmers clearly understand these topics and can convey them to customers and partners.

Responsible engagement is not only characterised by the interactions with the users of the technology on a day-to-day basis, but also to what extent the carbon revenues benefit the farmers. In the case of Sistema.bio's projects, the carbon revenue is used to lower the sales price of the digesters directly and substantially. In this way, farmers can benefit from the carbon revenue upfront, rather than over a long period of time. While the exact amount of carbon subsidy varies and is dependent on many factors, the price reductions are generally in the range of 30 to 90%. Factors influencing this share

[6] The following resources by Gold Standard elaborate on this:
https://www.goldstandard.org/articles/how-shared-value-calculated-gold-standard-certified-projects
https://www.goldstandard.org/sites/default/files/vivid_economics_ics_valuation_june2019.pdf
[7] See blog article: https://www.goldstandard.org/blog-item/report-valuating-benefits-improved-cooking-solutions.

can, for instance, be the price of credits that Sistema.bio is able to obtain, other project-related costs such as staff and financing, the size of the system, or taxes in the host country.

Ensure safeguards are in place to prevent any negative effects on humans or the environment

Projects whose positive impact on one aspect would be cancelled out by negative effects on the environment for instance, would no longer be considered "high quality". The Core Carbon Principles contain two specific requirements in this context, namely that **1)** the project shall have sustainable development benefits and safeguards, and **2)** contribute to a net zero transition.

Box 1: Core Carbon Principles

The Core Carbon Principles (CCPs) were released in 2023 by the Integrity Council for Voluntary Carbon Markets (IC-VCM), after extensive consultations with industry players, NGOs and other stakeholders. The underlying rationale of the development of the CCPs was the idea that in order to scale the voluntary carbon market, a minimum threshold of what constitutes a "high-quality" carbon credit would be required. With the principles having been published, the next step is for Multi-Stakeholder Working Groups to review in more detail specific carbon project categories and methodologies, including household biogas.

The former seeks to ensure that the carbon registry has clear guidance, tools and compliance procedures to ensure projects conform with industry best practices on social and environmental safeguards.[8] Gold Standard mirrors this sentiment in its *Safeguarding Principles & Requirements*.[9] Not only are projects required to contribute to at least three of the 15 SDGs in order to be eligible, they must also minimise and mitigate potential negative impacts on human rights, the environment, and cultural heritage, among others. Sistema.bio's carbon projects are assessed against these requirements during the registration project, both by its own team as well as independent third parties.

Furthermore, in the context of the clean cooking sector, the Clean Cooking Alliance's *Interim Principles for Responsible Carbon Finance in Clean Cooking* stipulates that project developers should avoid creating excessive market distortion in clean and improved cooking markets. The reason behind this requirement is that some developers opt to distribute their stoves for free, as the carbon revenue by itself is alone to generate sufficient revenues. In many cases, the stoves distributed are low-tier stoves with a limited lifetime of 2-3 years.[10] While this allows for a faster roll-out of the project technology, it drives local producers out of the market. Local artisans cannot compete against a free product and are thus likely to go out of business. This is less applicable to the case of Sistema.bio. Few countries that Sistema.bio operates in have a local biogas market or manufacturers of biogas systems. The main competing technologies are generally fixed-dome systems built locally from clay or lower-quality pre-fabricated systems imported from China. Both technologies come with significant drawbacks and are not as technologically advanced as the Sistema.bio digesters. More importantly, farmers still pay a considerable (yet affordable) price for their systems that would be more expensive than any locally-produced system. This is because carbon finance does not cover the full price of the technology, as well as the long-term after-sales service, which it does, for instance, in the case of lower-tier cookstoves. In many cases Sistema.bio helps to establish a local market for biogas raising awareness of the technology among farmers and creating capacity and skilled labour.

The second Core Carbon Principle applicable to this category is the project's contribution to a net zero transition, and thus avoidance of fossil-fuel locking. While relatively new to carbon markets, the requirement aligns with the overall spirit of the Paris Agreement. Whereas under the CDM, fuel switching projects, such as switching from coal to natural gas, were still eligible, these project types contravene the aim of the Paris Agreement to reach net-zero globally by 2050. This is because fossil-

[8] For more information on the Core Carbon Principles see: https://icvcm.org/the-core-carbon-principles/

[9] The Safeguarding Principles & Requirements can be accessed here: https://globalgoals.goldstandard.org/standards/103_V1.2_PAR_Safeguarding-Principles-Requirements.pdf.

[10] Cookstoves are commonly classified into 5 tiers, with 5 being the highest and 0 benign the lowest. More information about these indicators can be found on the Clean Cooking Alliance's website: https://cleancooking.org/news/10-16-2018-five-things-to-know-about-iso-s-new-clean-cooking-performance-targets/.

fuel infrastructure built today would continue to operate for many years, and thus make it more difficult to achieve the deep emission cuts needed across economies within this decade and the next. As a completely renewable fuel, biogas is clearly aligned with a net-zero future.

How can the impact of a carbon project be quantified accurately?

The second dimension to evaluate carbon projects against is whether the social and environmental impacts of the project are represented conservatively and accurately. While there are many ways to approach this topic, for the purposes of this paper the four criteria set out by the Core Carbon Principles with regards to emissions impact serve as the starting point. Other initiatives and insights from academia will be referenced throughout.

Additionality

This concept has been at the core of carbon markets since the early beginnings.[11] Generating carbon credits against a baseline, or business as usual scenario, implies that carbon finance must play a crucial role in enabling it. In other words, the project proponent must show that the project activity would not have taken place without the revenue from the carbon credits. Otherwise, it would be difficult for the impact generated by the project to be attributed to carbon finance. In practice, assessing whether carbon finance is indeed the sole enabler can be complex. Voluntary carbon standards[12] have put in place elaborate frameworks for the assessment of this criteria. Whether or not a project is "additional" further depends on the location and period during which it is implemented. A good example is the renewable energy sector. A solar photovoltaic (PV) plant is likely to be commercially viable without carbon finance in Spain, while a similar plant in a least developed country (LDC) may not. Moreover, as the renewable energy sector scales and costs decrease, so does the need for carbon finance. As a response to these developments, Gold Standard and Verra have increasingly restricted the admission of grid-connected renewable energy to their platforms. The continuous evolution of the additionality standards is a key reason why credits that have been issued more recently tend to be perceived as being higher in quality.

Household biogas digesters are considered highly additional in the carbon market context. The CDM Executive Board, a United Nations body tasked with drafting technical guidelines for the CDM, provides an up-to-date list of technologies which are considered "automatically additional." This Tool includes "digesters used in biogas generation from anaerobic treatment of wastes (e.g., kitchen, vegetable, animal and farm) where the resulting biogas is used for heat production for cooking purpose," and "where the users of the technology/measure are households or communities or small and medium enterprises (SMEs)." This provides a strong indication that there is a pressing need for carbon financing to support the advancement of biogas technology.

Besides this technical additionality analysis, the need for carbon finance becomes evident when examining the average farmer that Sistema.bio services. Without carbon finance even a small-scale Sistema.bio system would cost upwards of USD $1,000, which is not feasible for most farmers in the relevant market segment.

Permanence

Some project types such as afforestation or protection of existing forests involve the risk of reversals. That is, there is a possibility that the impact generated by the project is cancelled out at a later stage in time. For instance, an afforestation project may remove carbon dioxide from the air over a span of thirty years and issue and sell carbon credits during this period. The trees planted could, however, be destroyed after this period for a variety of reasons, including natural disasters. Every credible carbon standard, thus, contains extensive procedures to safeguard the integrity of credits that have been issued. However, permanence is primarily relevant in the carbon removal category, as opposed to emission reductions from methane avoidance and clean cooking. Specifically thinking about the methane component of Sistema.bio's carbon projects, each tonne of methane that was captured and

[11] The first Tool for demonstrating additionality under the CDM was published as early as 2004. See the link below for the different versions and revisions that this tool has undergone during the last 20 years.
https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-01-v5.2.pdf/history_view.

[12] A carbon standard refers to the complete set of rules, procedures, and methodologies according to which certified carbon credits are generated and issued. https://vcmprimer.org/chapter-7-carbon-standards-in-the-voluntary-carbon-market/.

destroyed by a biogas system cannot enter back into the atmosphere. Even if the technology were to be abandoned after a certain period, the greenhouse gas emissions that were not emitted into the atmosphere during this period retain their integrity.

Robust quantification of emission reductions and removals

This is arguably the most important, yet also the most complex component.[13]. **In general, a robust quantification is the result of two separate components: a credible baseline, and adequate monitoring procedures.** In simple terms, all emission reductions are calculated against a business-as-usual scenario called "baseline." This entails assessing what the emissions under the status quo (i.e., before the project intervention) are over a certain period and what they are after the project has been implemented. The difference between the two is generally the number of emissions that have been reduced. For example, a household replacing their light bulb with a more energy efficient model could calculate the electricity consumption during the year prior to switching the light bulbs and compare it with the consumption in the first year after the light bulb has been installed. The difference between the two, multiplied with the emissions intensity of the electricity source (e.g., the national electricity grid) will allow the household to calculate the emission reductions it has achieved by switching their light bulb. However, many carbon projects (biogas projects included) do not consist of a single project intervention, but instead distribute thousands of systems often within rural and complex socio-economic environments. Recent and accurate data sets are rarely available to project developers, making the baseline-setting a difficult task.

For biogas carbon projects, the most important element that describes the rules and procedures to establish a baseline and design a monitoring plan is Gold Standard's *Methodology for Animal Manure Management and Biogas Use for Thermal Generation*.[14] Published in October 2022, it consolidates and expands upon previous methodologies that had been developed over the past two decades. Under this methodology, biodigesters generate emission reductions from two sources - methane avoidance and the displacement of unsustainable biomass for cooking purposes. While the former makes up for most emission reductions in all of Sistema.bio's existing projects, the exact share varies due to a number of factors. For instance, liquefied petroleum gas (LPG) is more widely available in India compared to Malawi, where the use of charcoal and firewood is more prevalent. While both have specific emissions factors, the emissions related to the burning of LPG are significantly lower than those of charcoal or firewood. In addition, the average system size installed by Sistema.bio in India is larger, and as a result the share of the methane avoidance component is larger in India (~90%) than it is in Malawi (~60%). In general, the quantification of the emission reductions from methane are relatively well understood and have thus been less controversial compared to other project categories in the voluntary carbon market. The "robust" quantification in the clean cooking sector has come increasingly under scrutiny from academia, leading to initiatives such as the Clean Cooking Alliance's *Principles for Responsible Carbon Finance*.

Robust baselines

The baseline for methane avoidance leverages the 2019 Intergovernmental Panel on Climate Change (IPCC) values, complemented with bottom-up data from the farms. Prior to the installation of the digester, information on the number of livestock and the manure management systems employed by the farmer is recorded into Sistema.bio's digital monitoring system. IPCC data and values are then used to determine the corresponding emissions in the baseline scenario.

Realistic and geography-specific baselines for the clean cooking component, based on conservative assumptions, are somewhat more complex and consists of three key elements.

Fraction of non-renewable biomass (fNRB)

The biomass savings achieved by the project stoves only result in emission reductions to the extent that the biomass used is unsustainable. In other words, only if wood is cut down at a faster rate than

[13] The Integrity Council for the Voluntary Carbon Market (IC-VCM) itself is currently in the process of forming so-called Multi-Stakeholder Working Groups (MSWGs), that will assess specific methodologies in a more detailed manner to ensure they are robust. CCP eligible carbon credits will only be generated by approved methodologies. However, the efforts of the IC-VCM build on work carried out over the course of the previous two decades.
[14] Methodology available here: https://globalgoals.goldstandard.org/433-ee-ics-methodology-for-animal-manure-management-and-biogas-use-for-thermal-energy-generation/.

it regrows, can the stove be said to have reduced greenhouse gas emissions. This balance is captured by the fraction of non-renewable biomass. All clean cooking methodologies, as well as the Gold Standard methodology for biogas reference Tool 30 of the CDM.[15] While Sistema.bio has followed approved methods to calculate project-specific fNRB factors for its projects (i.e. CDM Tool 30), it is aware that these have often led to overestimated results in the past. To address these concerns the United Nations Framework Convention on Climate Change (UNFCCC) is introducing a new model to calculate the fNRB, called MoFuSS (Modelling Fuelwood Savings Scenarios). This modelling tool is more granular than the CDM Tool, as it calculates the biomass consumption at a pixel level (ha/km2) instead of at the jurisdictional level. In addition, the World Health Organization has published new data sets on household air pollution and cooking behaviour, which further contribute to a more precise estimate of the fNRB. The proposal by the UNFCCC underwent public consultation until January 2024 and a decision is expected to be made in the course of 2024. So far, preliminary fNRB values for countries in sub-Saharan Africa have been provided, while for Central America and South Asia / Southeast Asia only regional fNRB values are available on a preliminary basis. Going forward, it is to be expected that the fNRB values used in projects will be significantly lower compared to what they have been in carbon markets previously. Sistema.bio is committed to adjusting its fNRB values once the guidance from the UN bodies has been finalised, and in line with best available scientific insights.

Baseline fuel consumption

The amount of biomass used for cooking purposes that is saved by a stove is directly linked to its emission reductions. Depending on the methodologies, project developers can choose between several options to determine the ex-ante values for biomass usage per household. These include the reliance on default values, literature, national or project survey data or field testing. Sistema.bio collects a full baseline data record for 100% of the farms in its projects and has multiple touchpoints with users given its 10-year customer journey. This includes the types and number of fuels used by households prior to the installation of the digesters. Each visit is recorded digitally through Taro Works. Sistema.bio has been reviewing and refining its surveys over the years to best align with the methodologies, ensuring they are comprehensive, robust and detailed. Moreover, these ex-ante values are revised again at a later stage, when conducting multi-day in-field tests in both project-and non-project households. This allows to account for changes in cooking behaviours over the course of the project lifetime, leading to more accurate results.

Emissions factors

Under the CDM, a number of countries did not want cookstove projects to generate credits for avoided deforestation. As a compromise, the emissions factors (i.e. the greenhouse gas (GHG) emissions emitted per unit of cooking fuel) relied upon was that of LPG, rather than charcoal and firewood. This leads to under-crediting, although newer methodologies, especially those of the voluntary carbon market that were not bound to the UNFCCC context, opted to rely on the fuel-specific emissions factors instead. As with the firewood to charcoal conversion, the Sistema.bio uses the emissions factors of the respective fuels, derived from the IPCC.

Robust monitoring

Once a credible baseline has been established, the next step is to put in place accurate monitoring procedures. Ultimately, the digesters only lead to emission reductions to the extent that they are being used. Academic research has rightly pointed out that stove users may opt to still cook certain dishes with their old stove due to a perceived better taste or use it alongside their new stove when cooking. Generally, there are three approaches to monitoring these aspects: **1)** surveys; **2)** multi-day field tests; and **3)** sensors. While the first option is the most common one across cookstove projects, the Gold Standard *Methodology for Animal Manure Management and Biogas Use for Thermal Generation* excludes the utilisation of simple surveys. Instead, the methodology prescribes the use of Kitchen Performance Tests (KPTs), which are carried out in the field and over a period of several

[15] CDM Tool 30 can be accessed here: https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-30-v3.0.pdf/history_view.

days[16], or the use of sensors. These tests are able to track more precisely the exact cooking habits of a given household.

Sistema.bio field staff and partners are specifically trained to carry out these KPTs, taking into account the various intricacies and complexities of carrying out testing directly in the field. The authors of the Berkeley study, for instance, come to the conclusion that "*KPTs, if done well, are reasonably robust, yet still have their weaknesses.*"[17] The main potential shortcoming cited by the authors is that the project households may adjust their cooking behaviour, knowing that they are part of this test. Moreover, if KPTs are not carried out frequently enough, they may lack a nuanced view of aspects such as seasonality. In addition to the extensive training in carrying out KPTs in a manner that addresses the two points, Sistema.bio is piloting sensors and biogas flow meters to introduce them as part of the continuous monitoring best practices identified by the Berkeley project. While the sensors are not yet feasible at scale due to their high costs, installing them at a statistically significant number of installations allows Sistema.bio to compare the results of the KPTs with those of the sensors. In addition to the KPTs and sensors, Sistema.bio is also carrying out surveys at a larger number of farms, to obtain additional information on the usage of the digester.

No double counting

Avoiding double counting is crucial to the integrity of any carbon credit. If more than one entity were to lay claim on a single emission reduction, the net outcome for the climate would be negative. Both project partners and farmers sign a waiver, where they declare not to claim any of the underlying environmental attributes that will be generated by the digesters.

All Sistema.bio carbon projects are registered at a carbon registry, such as Gold Standard. Each project is given a unique identifier, and each of the carbon credits issued via this registry is linked to a unique serial number. The same applies to each farmer and digester in Sistema.bio's database, which undergoes additional quality control procedures to ensure the data is accurate. Moreover, auditors review during the validation and each verification process whether or not sufficient procedural safeguards are in place to avoid double counting and how the project proponent can prove that no carbon credits are issued and claimed through any other means.

What role do external certification bodies play?

The third and final key dimension to evaluate carbon projects is whether the project is listed on a public registry and vetted by an independent third party. Registries are an essential element of voluntary carbon markets. It is, thus, no surprise that the CCPs include quality requirements on a registry level and not just on a project or methodology level. A registry provides a platform where projects are listed, tracked, and information is made available to the public. With the exception of Sistema.bio's projects under Article 6 of the Paris Agreement, where projects are registered in national registries, all of its carbon projects are registered under the Gold Standard. This carbon standard is arguably the most reputable voluntary carbon standard, with a strong NGO supporter network that includes Worldwide Fund for Nature (WWF), International Union for Conservation of Nature (IUCN) and Fairtrade.[18]

Gold Standard requires validation to take place at the point of registration and every five years upon renewal of the crediting period. Its main purpose is to examine the counter-factual scenario described by the project proponent and ensure that the project complies with the rules and requirements of the carbon standard. Verification is carried out at each issuance, where the auditor will scrutinise the exact impact claimed by the project proponent over a certain period of time. Generally, carbon standards provide a list of Validation and Verification Bodies (VVBs) that are authorised to carry out this work.

Part 1 has provided an overview of what constitutes a high-quality and high-impact project, including how their impact can be accurately quantified and what role external certification bodies play. It

[16] Version 4.0 of the KPT manual can be accessed here: https://cleancooking.org/binary-data/DOCUMENT/file/000/000/604-1.pdf.
[17] Gill-Wiehl et al; *Pervasive over-crediting from cookstove offset methodologies*; 2024. https://www.nature.com/articles/s41893-023-01259-6.
[18] More on the governance structure of Gold Standard can be found here: https://www.goldstandard.org/about-us/governance.

discusses how Sistema.bio's biogas projects meet key criteria (creating value to users and the environment; engaging in a meaningful and responsible way with end users; and putting in place safeguards to prevent negative effects on humans or the environment) and Core Carbon Principles (additionality; permanence; robust quantification of emission reductions and removals; and no double counting). **Part 2** turns to a discussion on managing carbon project risks, including how Sistema.bio has aimed to mitigate them.

Part 2: Managing (Carbon) Project Risks

This part outlines the different risk categories associated with developing, financing and delivering emissions reductions and how Sistema.bio has sought to mitigate them. Moreover, it summarises how these risks can affect the actors involved in different ways, including financiers, carbon credit buyers, project developers, farmers and governments.

How do commercial structures affect risk?

It is important to note that the risks and their effects can be assumed by different actors, and ultimately depend on the commercial agreement between parties. The most common structure employed by Sistema.bio is shown in **Figure 5** below.

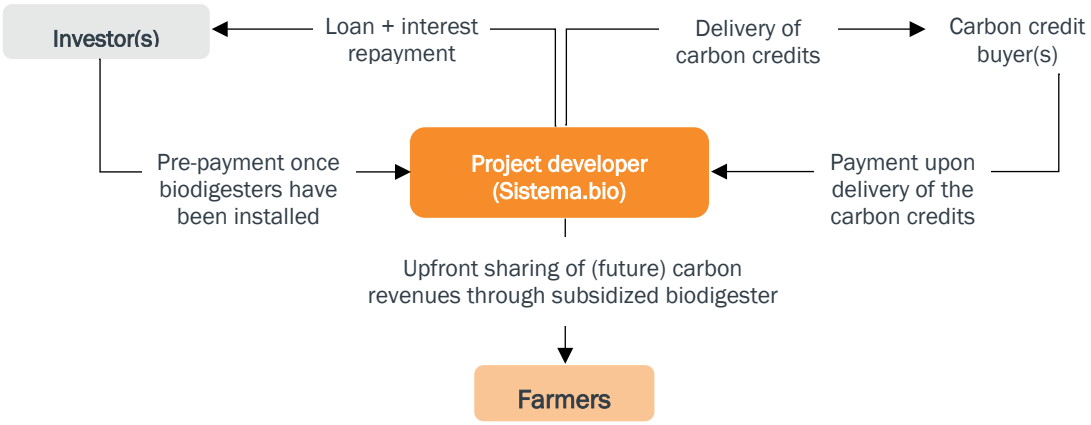

Figure 5: The most common commercial structure for Sistema.bio carbon projects

In practice, this set-up leads to Sistema.bio internalising several risks. For instance, it is pre-paying for the manufacturing and successful implementation of the digester, only receiving the pre-finance from the investors once the digester has proven to be installed. More importantly, it is shielding the farmers from all volumetric or market risks. By leveraging future (i.e. expected) carbon revenues, it can subsidise the digester at the point of sale. Afterwards, the farmers are no longer exposed to any project risks.

While governments are not explicitly mentioned in **Figure 5**, they play an important role in creating an overall enabling environment. As such, they are (generally) not a direct participant in the projects, but instead provide additional rules and procedures, often centred around safeguarding the farmers.

Smaller project developers may not possess access to sufficient working capital to be able to bridge the gap between manufacturing and installation. In this case, the investor, or carbon credit buyer would need to pay a larger amount upfront, thereby significantly altering the risk profile, and thus likely resulting in higher interest rates. This, in turn, would raise the overall financing costs for the project, leaving less funding available to subsidise the product. Thanks to its scale and experience, Sistema.bio can access this working capital, assuming more of the risks, as outlined in the table below.

What are the risks related to the development of a carbon project?

Table 1 lists the project-related risks associated with biogas carbon projects:

Table 1: Risk categories and mitigation measures by Sistema.bio

Risk category	Description	Effects on different actors	Mitigation measures
Implementation	This describes the level of risk related to the potential for the project to be implemented as designed. This includes the technical and biodigester installation.	In the case of Sistema.bio, it is the developer itself that is assuming this risk, since the investors only pay once the biodigesters have been installed. Delays in implementation may influence the total number of credits generated over the crediting period. Thus, while investors or carbon credit buyers are not immediately affected financially, there is a volumetric component to it.	Sistema.bio has installed over 100,000 systems across the globe, in a wide spectrum of different socio-economic circumstances. Moreover, by owning manufacturing facilities in Mexico and India, Sistema.bio is less reliant on external parties to procure the technology. Together with its long track-record, this significantly reduces implementation risk.
Registration, validation and certification	This describes the risk that the standard or third-party auditor will question the assumptions of the use of a given methodology during the registration or certification process.	If the project fails to achieve certification under a standard, it would not be able to generate carbon credits, negatively affecting all actors involved. The investors would not be able to recoup their investment, the buyer of the credits would need to procure alternative volumes, farmers would not be able to obtain the technology at a reduced price, and the developer would not be able to expand into the country.	Sistema.bio has built in-house capacity to design, register and certify carbon projects. It has successfully certified carbon projects under its own name in Uganda, India and Mexico, with another project in Kenya currently listed and undergoing validation. It has also collaborated with technical partners to certify projects in Malawi, Kenya and India. The company has a dedicated Carbon & Impact team of six people (as of February 2024), whose core focus is the managing of the carbon portfolio. This is complemented by an external, technical consultant with over 20 years of experience in carbon markets.

Performance	This describes the performance risk once the project is implemented and certified, which comprises adoption rates, use patterns and usage rates of a project over time.	Similar to delays in the implementation, an under-performance in terms of technology adoption and usage would likely result in less carbon credits than expected. For the investors, less credits sold would result in a lower return on the investment. Corporate buyers normally only pay upon delivery of the units but would need to procure alternative volumes on the secondary market. A major benefit of signing long-term offtake agreements from a buyer's perspective is the price certainty. In case a project under-performs, the buyer may have to pay significantly more for their units than initially planned for. As a consequence of the previous two, the developer would most likely also receive less revenues, although this is dependent on the exact commercial agreement between the investor, buyer and developer. There would not be an immediate effect on farmers, as the farmers already receive the carbon revenues upfront, via the subsidy of the biodigesters.	Extensive procedures were designed and improved over the years by Sistema.bio to ensure high adoption rates. When the digester is being installed, farmers receive elaborate training on how to use and service their digester. Easy-to-read user manuals in local languages are provided in addition to the training. Next, all farms are visited six months after installation to address service requests or questions that farmers may have. Farmers are considered long-term partners rather than just clients, as their satisfaction can unlock new opportunities. When forecasting these rates, Sistema.bio is relying on 10 years of experience and making conservative forecasts.
Verification and Issuance	This describes the risk that proper monitoring, verification (third-party) and reporting (MRV) will happen to ensure that the standard being used will have all the evidence required to issue carbon credits. This is focused on the MRV quality and capacity to	This becomes ultimately a volumetric risk for investors, buyers and the developers. Countries would only be affected by volumetric risks to the extent that they rely on the project for	The data collection and handling process at Sistema.bio was designed to accommodate the monitoring, verification and issuance processes of carbon standards. Data is kept in a global, digital database, and the carbon team comprises several team

	accomplish a series of reports and coordination with third parties in a timely and professional manner at predetermined time frames.	their own compliance purposes under the Paris Agreement.	members whose core focus is to ensure the quality of the data is of the highest level.
Delivery	This represents the risk of delivery of the carbon credits to the buyer in such a way that ensures that they are able to repay any debt or be available for sale to deliver return expectations of the project. This risk is associated with the Standard that is used to certify the project and the legal fulfilment of any project intermediaries that may be linked to any given project. This includes any political risk, or legal restrictions related to delivering carbon credits from a given geography.	If carbon credits cannot be delivered to the buyer, for whatever reason, payment to the developer or investor cannot take place. This would mean that these two actors cannot recoup their investments. For the buyer, it could have the effect of having to procure volumes at the secondary market, which has already been mentioned. While in most cases this would not have a direct effect on farmers and the host country government, it could negatively affect future projects.	Sistema.bio's projects are certified by the Gold Standard which is arguably the most reputable carbon standard in the voluntary carbon market, with a robust governance structure and reliable digital infrastructure. This significantly reduces the delivery risks from a technical standpoint. With regards to political risks, extensive work is carried out prior to making the decision to develop a carbon project in a specific host country. This includes both desk research and assessment of the country's targets under the Paris Agreement, as well as direct contact with the authorities. For investors, Sistema.bio's portfolio approach further diversifies these risks. Having a mixture of various host countries, but also a mix of voluntary and compliance market projects, reduces the overall risk profile.

Reputational	This describes the risk of negative press coverage due to a flaw in the project design, or incomplete communication by the end user of the carbon credit.	Reputation risks are likely to affect the developer the most. Ultimately, it is the developers who carry the key responsibility to design the project and put sufficient safeguards in place. Next, investors and buyers would likely also be affected, depending on how closely they are affiliated with the project and what has been communicated in the past.	Sistema.bio works closely with specific projects that the buyer or investor knows well to carry out a due diligence process that decreases reputational risks significantly, when compared with purchasing carbon credits on the secondary market. External distribution partners undergo a due diligence process prior to being selected and are contractually held to those same standards. Sistema.bio's approach of investing into a country portfolio, with the same underlying technology and approach already, constitutes a further mitigation measure. Finally, Sistema.bio is staying informed regarding the latest developments and scientific research. This includes technical aspects such as the quantification of the emission reductions, but also compliance of its employees and partners with best practices in the fields of human rights and stakeholder participation.

Conclusion

While the evolution of carbon reduction efforts has not been linear, the science is clear that significant focus must come from all countries and industries to reduce carbon emissions. The carbon markets seem to be a mechanism that will remain for some time, as becomes evident from the prominent role they play within the Paris Agreement. Current efforts to improve the quality and trust in the underlying assets of carbon markets will go a long way to ensure that carbon markets can deliver true reduction of emissions and other associated impacts that carbon projects can have on global development.

As this paper has attempted to show, there are ultimately three key criteria that make a "high-quality and high-impact" carbon project. First, the project itself must create significant value to its users, and the environment, thus contributing to sustainable development. Second, the quantification of the impact, including the emission reductions and co-benefits, must be quantified accurately, based on conservative assumptions. In practice, this includes setting credible baselines and putting in place robust monitoring procedures. Third, a project should be registered with a carbon standard that has implemented a strong governance framework and allows public and transparent access to key project documentation.

Sistema.bio anticipates that there will be a continued development of the rules and regulations that govern carbon markets and that there will be long-term efforts for the compliance markets and VCMs to converge in some aspects. In the meantime, Sistema.bio will continue to adhere to the best practices, which will likely be incorporated in the future regulations.

With regards to carbon project risks, the paper has provided an overview of the different risk categories, how they can affect the different actors involved, and most importantly how they can be mitigated based on Sistema.bio's experience. When seeking partnerships for the development of projects, the company will use the risk framework presented here to ensure that it is clear how to manage the risk of each phase of implementation and ensure that project partners, investors, carbon buyers and farmers all understand the risks associated and are aligned to minimise those risks.

By focusing on the highest quality and integrity projects, and alignment project partnerships to share and minimise risks, Sistema.bio can continue on its journey to reduce 1% of all annual GHGs.