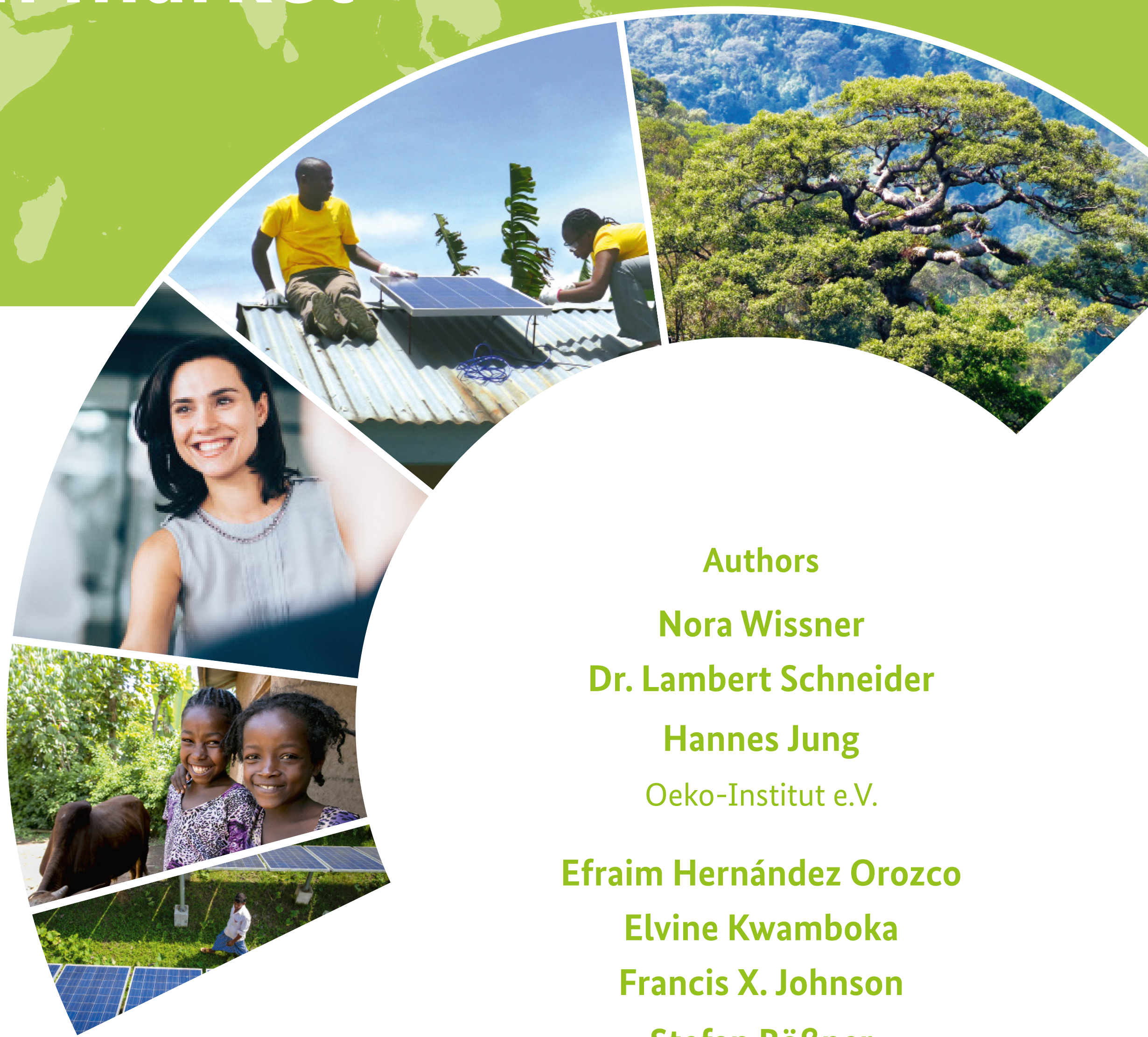
STUDY

Sustainable development impacts of selected project types in the voluntary carbon market



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List of Abbreviations

CFM	Community Forest Management
GHG	Greenhouse Gas
HAP	Household Air Pollution
ICS	Improved Cookstove(s)
LPG	Liquefied Petroleum Gas
NDC	Nationally Determined Contributions
PV	Photovoltaic
SDG	Sustainable Development Goal
TV	Television
VCM	Voluntary Carbon Market
WHO	World Health Organization

Summary

There is increasing acknowledgement that projects in the voluntary carbon market have an impact beyond reducing greenhouse gas emissions. Projects can have additional positive effects on sustainable development, but they can also impair progress on certain sustainable development goals.

This paper assesses the sustainable development impact of four selected project types of the voluntary carbon market: afforestation, improved cookstoves, off-grid photovoltaics and water filters. The assessment draws on the Agenda 2030 with its sustainable development goals and targets as a framework for the analysis.

The results show that all the selected project types have positive sustainable development impacts beyond greenhouse gas emission reductions. Overall, positive impacts were identified for one third to about half of the analyzed sustainable development targets, depending on the project type. Only a few negative impacts were identified.

The assessment also shows that sustainable development impacts are highly contextual. Generalized impacts identified in this report might vary for individual projects in different local contexts. This holds in particular for afforestation projects: many positive impacts were identified but most are also subject to uncertainty depending on the project design and local context.

Improved cookstoves projects seem to positively influence the highest number of targets. Interestingly, the estimated reduction in air pollution from deploying improved cookstoves is still insufficient to meet WHO recommendations. The assessment also identified many positive sustainable development impacts of off-grid photovoltaics projects, with the main drawback being the end-of-life treatment of the installations. Even though water filter projects are gaining increasing attention in the market, we could not identify a large number of impacts. The sustainable development impact of water filter projects particularly depends on the baseline scenario: boiling water or using untreated water result in very different sustainable development impacts (for example regarding health benefits).

The paper also identified several methodological challenges. For example, the time horizon is an important consideration for assessing sustainable development impacts. For all project types assessed, the impact can significantly change depending on how the devices and installations are maintained throughout the lifetime of the project or how the afforested land is managed and preserved in the long run.

The sustainable development impacts identified in this paper are based on generalized project types of the voluntary carbon market. The results from this paper can be used as an indication of the number and the kind of SDG impacts which can be typically expected from the four project types. Buyers of carbon credits are encouraged to always seek out project-specific information to assess whether the generalized impacts presented here are applicable to the respective project in question. Additionally, carbon credit buyers can achieve further assurance on sustainable development impacts by choosing a carbon crediting program that has robust environmental and social safeguards and provides for a sound assessment of sustainable development impacts.

Kurzfassung

Es wird zunehmend wahrgenommen, dass Projekte auf dem freiwilligen Kohlenstoffmarkt eine Wirkung haben, die über die Reduzierung von Treibhausgasemissionen hinausgeht. Projekte können zusätzliche positive Auswirkungen auf eine nachhaltige Entwicklung haben, aber sie können auch den Fortschritt bei bestimmten Zielen der nachhaltigen Entwicklung beeinträchtigen.

In diesem Papier werden die Auswirkungen von vier ausgewählten Projekttypen des freiwilligen Kohlenstoffmarktes auf eine nachhaltige Entwicklung ausgewertet: Aufforstung, verbesserte Kochherde, netzunabhängige Photovoltaik und Wasserfilter. Die Bewertung stützt sich auf die Agenda 2030 mit ihren nachhaltigen Entwicklungszielen und -unterzielen als Rahmen für die Analyse.

Die Ergebnisse zeigen, dass alle ausgewählten Projekttypen neben der Verringerung der Treibhausgasemissionen auch positive Auswirkungen auf eine nachhaltige Entwicklung haben. Insgesamt wurden je nach Projekttyp für ein Drittel bis etwa die Hälfte der analysierten Ziele für nachhaltige Entwicklung positive Auswirkungen festgestellt. Es wurden nur wenige negative Auswirkungen festgestellt.

Die Bewertung zeigt auch, dass die Auswirkungen auf eine nachhaltige Entwicklung sehr kontextabhängig sind. Die verallgemeinerten Auswirkungen, die in diesem Bericht identifiziert wurden, können für einzelne Projekte in unterschiedlichen lokalen Kontexten variieren. Dies gilt insbesondere für Aufforstungsprojekte: Es wurden viele positive Auswirkungen festgestellt, aber die meisten sind mit Unsicherheiten behaftet, die von der Projektentwicklung und dem lokalen Kontext abhängen.

Projekte zur Verbesserung von Kochherden scheinen die meisten Ziele positiv zu beeinflussen. Interessanterweise ist die geschätzte Verringerung der Luftverschmutzung durch den Einsatz verbesserter Kochherde immer noch nicht ausreichend, um die Empfehlungen der Weltgesundheitsorganisation zu erfüllen. Bei der Bewertung wurden auch viele positive Auswirkungen von netzunabhängigen Photovoltaik-Projekten auf die nachhaltige Entwicklung festgestellt, wobei der größte Nachteil die Entsorgung der Anlagen am Ende ihrer Lebensdauer ist. Obwohl Wasserfilterprojekte auf dem Markt zunehmend an Bedeutung gewinnen, können wir keine große Anzahl von Auswirkungen feststellen. Die Auswirkungen von Wasserfilterprojekten auf eine nachhaltige Entwicklung hängen insbesondere vom Ausgangsszenario ab: Das Abkochen von Wasser oder die Verwendung von unbehandeltem Wasser führen zu sehr unterschiedlichen Auswirkungen auf eine nachhaltige Entwicklung (z. B. in Bezug auf den Gesundheitsnutzen).

In dem Papier werden auch mehrere methodische Herausforderungen genannt. So ist beispielsweise der Zeithorizont ein wichtiger Aspekt bei der Bewertung der Auswirkungen auf eine nachhaltige Entwicklung. Bei allen untersuchten Projekttypen können sich die Auswirkungen erheblich verändern, je nachdem, wie die Geräte und Anlagen während der gesamten Lebensdauer des Projekts gewartet werden oder wie das aufgeforstete Land langfristig bewirtschaftet und erhalten wird.

Die in diesem Papier ermittelten Auswirkungen auf die nachhaltige Entwicklung basieren auf verallgemeinerten Projekttypen des freiwilligen Kohlenstoffmarktes. Die Ergebnisse dieses Papiers können als Hinweis auf die Anzahl und die Art der Nachhaltigkeitswirkungen dienen, die typischerweise von den vier Projekttypen erwartet werden können. Käufern und Käuferinnen von Emissionsgutschriften wird empfohlen, stets projektspezifische Informationen einzuholen, um zu beurteilen, ob die hier dargestellten generellen Auswirkungen auf das jeweilige Projekt zutreffen. Darüber hinaus können die Käufer und Käuferinnen von Emissionsgutschriften mehr Gewissheit bezüglich der zu erwartenden Auswirkungen auf die Entwicklung erlangen, indem sie sich für ein Programm entscheiden, das über solide Umwelt- und soziale Schutzmaßnahmen verfügt und eine fundierte Bewertung der Auswirkungen auf die nachhaltige Entwicklung vorsieht.

1. Introduction

There is increasing acknowledgement that projects in the voluntary carbon market (VCM) have an impact beyond reducing greenhouse gas (GHG) emissions. Projects can have additional positive effects on sustainable development, such as reducing indoor air pollution through efficient cookstoves, but may also have negative impacts, such as resettlements in the context of large-scale hydro power projects. Climate change mitigation and sustainable development are strongly interlinked as sustainable development can facilitate the necessary transition required for limiting global warming to 1.5°C and vice versa (ICAT 2020; Kolenda et al. 2020; Roy et al. 2018). For example, transforming cities to be more resilient and adaptive for climate change can benefit the urban population by reducing traffic, creating shade and greenery. Vice versa, protecting ecosystems and biodiversity can at the same time increase carbon stocks, like marshlands. It is thus important to leverage these positive development impacts of projects in the VCM. Carbon crediting programs are increasingly developing approaches to assess and document positive and negative sustainable development impacts. This includes requirements or tools to assess sustainable development benefits from projects and make them visible, as well as social and environmental safeguards to avoid, minimize and mitigate adverse impacts (Gold Standard Foundation (2019); Wissner and Schneider (2022).

Promoting positive impacts on sustainable development of projects in the VCM will become more relevant in the future as interest of carbon credit buyers in these benefits is increasing and because the timeframe for the Agenda 2030 is closing in (United Nations 2015b). The VCM has grown considerably in recent years – exceeding a market size of a traded value of 1 billion USD in 2021 (Ecosystem Marketplace 2021b). Additionality, the adoption of rules for Article 6 of the Paris Agreement at COP26 in November 2021 enables buyers in the VCM to use carbon credits that have been authorized under Article 6.2, thereby avoiding double claiming with nationally determined contributions (NDCs). The likely continuing growth of the market makes it even more important that carbon credit programs properly and transparently assess sustainable development impacts and that carbon credit buyers are aware of the potential synergies and trade-offs between climate change mitigation and sustainable development by projects in the VCM.

While carbon credit programs increasingly aim to label and document sustainable development impacts, there is little information available for carbon credit buyers to date on what impacts can be typically expected from different project types. With this paper, we aim to provide an overview of typical positive and negative sustainable development impacts of four selected project types in the VCM. The paper thereby also illustrates how carbon credit buyers and any interested stakeholders could evaluate sustainable development impacts associated with different project types using a systematic and structured framework.

This paper first provides a classification of project types in the VCM (chapter 2). Based on this classification, four project types are selected: afforestation, improved cookstoves, off-grid photovoltaic, and water filters. The methodological approach is described in chapter 3. The typical sustainable development impacts of the four selected project types are described in chapter 4. The paper concludes with recommendations for carbon credit buyers in the final chapter.

2. Classification and selection of project types

This chapter provides a classification of important project types in the VCM. This classification draws on analyses of the VCM market, such as the Ecosystem Marketplace (2021a) and the database by the Berkeley Carbon Trading Project[1], and classifications used elsewhere, like the Clean Development Mechanism (CDM) pipeline by (UNEP 2021), or relevant studies, like Warnecke et al. (2017). We approach the classification from a sectoral perspective and distinguish between broader project type categories, project types and sub-types of projects. Table 1 provides an overview of the classification.

This classification has been used to select the project types for an in-depth analysis. The authors and the client selected together four project types which cover different sectors, mitigation potentials, shares in the VCM and relevance for the Global South.

Table 1: **Overview of project types**

Project type category	Project type
Renewables	Wind power, hydropower, solar power/heat, geothermal power/heat, biomass power/heat, tidal power, biofuels, green hydrogen
Energy industries	Reduction in oil and gas flaring, leak reduction in natural gas infrastructure, coal mine methane capture, methane reduction from charcoal production
Energy efficiency supply-side	Waste heat recovery, combined heat and power, new efficient fossil fuel power plants, district heating, efficient electricity transmission & distribution
Energy efficiency demand-side & households	Efficient household appliances, household biodigesters, household water supply, building insulations
Fossil fuel switch	New natural gas power plants, fossil fuel switch in existing plants
Transport	Fleet efficiency, modal shift
Industrial emissions	Ozone depleting substances/refrigerants, cement blending, N_2O from adipic acid, N_2O from nitric acid, N_2O from caprolactam, PFCs from aluminum production, SF_6 from magnesia production, SF_6 from transformers, HFC_{23} from $HCFC_{22}$ production
Carbon capture	Carbon Capture and Storage (CCS), Carbon Capture and Utilization (CCU)
Waste	Landfill gas capture, methane reduction from wastewater, composting, recycling, municipal solid waste (MSW) incineration
Agriculture	Manure management, methane reduction from rice cultivation, methane reduction from ruminants, N_2O reduction from fertilizer application
Land-use change and land management	Afforestation/reforestation, avoided deforestation and forest degradation, improved forest management, improved grassland management, improved cropland management, peatland restoration, avoided conversion or degradation of peatlands, coastal wetland restoration, avoided conversion or degradation of coastal wetlands, jurisdictional REDD+

Source: Authors' own analysis based on Warnecke et al. (2017), UNEP (2021), UNFCCC CDM Database for PAs and PoAs[2] and the Voluntary Registry Offsets Database by Berkeley Carbon Trading Project[3]

[1] Voluntary Registry Offsets Database by Berkeley Carbon Trading Project: https://gspp.berkeley.edu/faculty-and-impact/centers/cepp/projects/berkeley-carbon-trading-project/offsets-database

[2] UNFCCC Database for PAs and PoAs, for download here: https://cdm.unfccc.int/Projects/projsearch.html

[3] Voluntary Registry Offsets Database by Berkeley Carbon Trading Project: https://gspp.berkeley.edu/faculty-and-impact/centers/cepp/projects/berkeley-carbon-trading-project/offsets-database

In the following, we define the four selected projects and describe briefly why they have been chosen:

- **Afforestation** (land-use change and land management): Afforestation is the establishment of a forest on previously non-forest land. It is difficult to differentiate further sub-types of afforestation as this depends on the context. Generally, it makes a difference for the mitigation potential and potential sustainable development impacts whether the afforested area consists of a monoculture of a single tree species or whether a species- and age-diverse forest is created. Sustainable development impacts will partially depend on these details of the implementation. Afforestation has been chosen due its popularity in the VCM and potential for GHG emission reductions, and as this project type involves removals.
- **Improved cookstoves** (energy efficiency demand-side & households): Efficient biomass cookstoves - or improved cookstoves (ICS) - are a very popular and wide-spread project sub-type in the VCM with good data and literature availability. A variety of impacts on sustainable development are expected.
- **Off-grid PV** (renewables): Expanding renewable energy generation is essential for climate change mitigation and thus an important category to include in the case studies. Where households do not have access to a reliable electricity grid, off-grid photovoltaic (PV) systems can be used to generate renewable electricity in remote places, in communities or individual households. This category has been chosen because access to electricity is considered to be essential for sustainable development.
- **Water filters** (energy efficiency demand-side & households): Water filters are used in households to purify drinking water. If water filters replace the boiling of contaminated water with fossil fuels or non-renewable biomass, the use of water filters can reduce GHG emissions. Water filter projects are currently a small category in the VCM but increasingly gain attention. Moreover, they can be expected to have high sustainable development impacts.

3. Methodological approach

This section describes our methodological approach to assessing typical sustainable development impacts of the selected project types.

For a structured and transparent assessment of sustainable development impacts, categories are useful. The Agenda 2030 with its sustainable development goals (SDGs), adopted in 2015 by the United Nations Member States (United Nations 2015b), is a very useful global framework for assessing the sustainable development impact of projects in the VCM in a systemic and standardized manner. The 17 SDGs, with their 169 targets, are highly interlinked (United Nations 2015a). The progress on one SDG often has an impact on other goals of the framework. From a carbon market perspective, the main purpose of projects in the VCM is to contribute to the achievement of SDG 13 (climate action).

In our further analysis, we assess the impacts of projects in the VCM on SDGs other than SDG 13 – or in other words the interlinkages between SDG 13 and other SDGs for the selected project types. We build on the method used by Oeko-Institut, WWF and EDF (2021) which draws on the concept of a 7-point ordinal scale from Nilsson et al. (2016). The scale helps to assess the interactions of SDGs by defining seven types of interactions from -3 to +3 which describes the qualitative nature of the interaction, rather than the magnitude of the interaction. Oeko-Institut, WWF and EDF (2021) build on this general scale to apply it in the context of assessing the SDG impact of projects or project types. Table 2 shows the different scorings and the associated SDG impact. Positive scores are highlighted in green and negative scores in red. An exemplary evaluation of SDG impacts at goal level with this method is shown in Table 3. The scoring ranges are colour-coded accordingly: solely positive ranges in green, a range of negative scores in red, and a range including a score of zero in yellow (see score of SDG 10 in Table 3). It is expected that SDG impacts will be contextual and therefore scores cannot be given without uncertainty (Hernández-Orozco et al. 2022). To account for this, the assessments work with ranges (as for SDG 10 in Table 3). A range indicates potential impacts under different circumstances. These circumstances are further described in the justification for each range in the summary tables in chapter 4.

Table 2: **Scoring approach for sustainable development impacts of project types in the VCM**

Impact of the project on the SDG	Scoring
Indivisible: The successful implementation of the project automatically delivers progress on this SDG.	3
Reinforcing: The successful implementation of the project directly makes it easier to make progress on this SDG.	2
Enabling: The successful implementation of the project indirectly creates conditions that enable progress on this SDG.	1
Consistent: There is no significant link between the project and this SDG.	0
Constraining: The successful implementation of the project constrains the options for how to deliver on this SDG.	−1
Counteracting: The successful implementation of the project makes it more difficult to make progress on this SDG.	−2
Cancelling: The successful implementation of the project automatically leads to a negative impact on this SDG.	−3

Source: Oeko-Institut, WWF and EDF (2021)

Table 3**: Exemplary evaluation of SDG impacts of a random carbon market project at SDG level**

SDG	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Score	1	0	0	0	-1	0	3	0	0	0 to 1	0	1	-	0	0	0	0

Source: Based on Oeko-Institut, WWF and EDF (2021).

While the assessment at goal level can provide a good rough estimate of the interaction, an analysis at target level provides a more refined approach and allows for a more detailed analysis of SDG impacts (Day et al. 2020). For example, the International Council of Science (2017) tests the approach of Nilsson et al. (2016) with four selected SDGs. Key interactions are analyzed at target level after a general analysis of the interaction at goal level. An analysis at target level better reflects that there could be positive as well as negative interactions on targets subsumed under one SDG. An assessment only at goal level is not able to properly reflect those cases. However, a comprehensive assessment of sustainable development impacts at target level requires more effort and time because the SDGs encompass 169 targets in total. Weitz et al. (2018), for example, apply the scale from Nilsson et al. (2016) in a cross-impact matrix and conduct a network analysis at national scale for Sweden. The study was conducted at target level as it was considered much more specific. Even though only two targets per SDG were selected as being relevant for the Swedish context, it still resulted in the large amount of 1122 interactions to be analyzed in total.

For the purpose of this study, only interactions between SDG 13 and other SDGs (and their respective targets) are considered relevant. Even though this reduces the number of targets (and potential impacts) to be assessed to 164 targets, a further limitation is necessary. Similar to Weitz et al. (2018), we therefore exclude the 'means of implementation' targets under each SDG and SDG 16 and 17 as they pertain mainly to government actions and are not directly translatable to carbon credit projects. Based on a preliminary literature research on the selected project types (chapter 2) and expert judgement of the authors, we have selected 13 SDGs and 36 targets for the analysis. An overview of the 36 targets can be found in Table 9 in the Annex.

The assessment of sustainable development impacts using the methodology described above (Table 2) is based on a literature review and expert judgment. Where there was a lack of available literature, evidence from implemented projects in the VCM has also been considered. This information was retrieved from program registries, e.g. the Gold Standard Impact registry.[4]

The assessment process includes two steps.

Firstly, the selected project types are defined based on the author's judgment of what projects in the voluntary carbon market typically entail and partially building on definitions used in the Carbon Credit Quality Initiative[5]. This includes a description of the measures undertaken under the project as well as a description of our assumed baseline scenario to which the impacts of the project are compared. Clarifying these assumptions is important, since both the mitigation measures and the baseline scenarios may vary among individual projects.

Secondly, the authors conduct an independent assessment of the impacts of each project type on the 36 targets by using the SDG Synergies Tool[6]. In parallel, a literature review is conducted to assess these. The literature review includes scientific literature as well as relevant grey literature, for example from organizations such as the World Bank. The literature is not necessarily specifically related to the VCM but assesses the impacts of the respective technology or practice more broadly. Subsequently, the scores for each target are compared between the independent assessment of the co-authors and the scores derived from the literature review. Finally, the scores are discussed among the experts and a conclusion on the most likely outcome is derived.

[4] Gold Standard Impact Registry: https://registry.goldstandard.org

[5] Carbon Credit Quality Initiative (CCQI): https://carboncreditquality.org/

[6] SDG Synergies Tool developed by Stockholm Environment Institute: https://www.sdgsynergies.org/

4. Case studies

This chapter presents the assessment of sustainable development impacts for each of the four selected project types. The assessments in Table 4 to Table 8 are based on a literature review and expert judgment as described in the previous chapter. For each project type, we first describe the project type and baseline scenario used for the assessment. We then discuss individual target scores, which are supported by detailed explanations, and general findings for the respective project type. Finally, we discuss the limitations of the applied methodology and summarize findings which pertain to all project types.

4.1 Afforestation

This section presents and discusses the assessment of sustainable development impacts of the project type *afforestation*.

For the purpose of this paper, afforestation projects are defined as the establishment of a forest on a non-forest land area that is ecologically appropriate for forests, avoiding establishment of forest on naturally non-forested biomes and excluding the boreal region (due to albedo-effects). The focus of the project type is the establishment and long-term increase of a carbon sink in the form of a natural forest. Any utilization of forest resources must be sustainable to ensure that the capacity of the forest as a carbon sink is at least maintained or enhanced. The tree species composition is based on the natural forest type of the area. This project type does not include the restoration of marine coastal ecosystems, such as mangroves.

Individual afforestation projects can be very different in their design and therefore in their impact. Impacts of a land-use change project such as afforestation depend significantly on the local context. Even though we narrowed down the project type in the project definition above, the assessment of a generalized "afforestation" project type is still associated with considerable uncertainties about the impacts. For example, monoculture afforestation would likely have negative sustainable development impacts on biodiversity (Seddon et al. 2020).

Compared to the other project types (sections 4.2 to 4.4), the scores for afforestation in Table 4 therefore include more ranges. Additionally, there is no universal definition of a "sustainable use" of forest resources. The use of forest resources, in contrast to a strictly protected forest with no access by local people, is included in the project type definition as this can enable a variety of positive sustainable development impacts and participation by the local people.

Table 4 shows the assessment of sustainable development impacts from the afforestation project type. The explanation for each target can be found in Table 9 in the annex. The assessment shows that 12 positive impacts on other targets are identified. 13 targets are assigned varying impacts (shown as ranges). Ranges generally indicate that the (positive and/or negative) impacts only unfold under certain conditions (chapter 3). This is due to the highly contextual nature of impacts from land-use change projects as mentioned above. No significant interaction could be identified with 11 of the 36 targets.

Generally, afforestation projects typically have a **positive impact on life on land** (SDG 15). The project type directly contributes to target 15.2 by increasing afforestation and promoting sustainable management of forests. Afforestation does not restore water-related ecosystems like forests, but it can promote the conservation and sustainable use of these ecosystems (target 15.1). If afforestation takes place on degraded land, the projects also contribute to target 15.3 by potentially stopping and in some cases reversing land degradation. And finally, a well-designed afforestation project can help to protect or even restore biodiversity (target 15.5). This effect depends on local biodiversity conditions and the biodiversity in the baseline scenario.

The contribution of an afforestation project to **poverty alleviation** (SDG 1) is highly contextual and depends on how forest resources are used. There are also trade-offs between short-term livelihood imperatives and the long timescales intrinsic to forest growth. Forests can help people diversify their income, accumulate savings and move out of poverty, e.g., through the sale of forest products, ecotourism and the enhancement of livelihoods-supporting ecosystem services. Especially cooperative approaches and community forest management (CFM) might yield significant benefits. Furthermore, forests are deemed safety nets which can smooth people's income and consumption in times of external shocks such as floods, landslides or pandemics. As the manifestation of these positive impacts depends on assumptions not included in the project definition, the score assigned to targets 1.1 and 1.2 ranges between zero and two.

Interestingly, there might be **mixed impacts on the goal of zero hunger** (SDG 2). To end hunger and increase access to food (target 2.1), protected forests can, on the one hand, increase pressure on food production systems by hindering their expansion in response to market shifts or climate change and degradation. On the other hand, forest-related food, such as fruits, seeds and wild meat, have an important role in the diet patterns of some communities - even more so in crises and after crop failure. Fuelwood for cooking, fodder trees and forest ecosystem services with positive externalities to agricultural systems can further benefit food security. Again, it should be emphasized that the long timescales intrinsic to forest growth hamper these benefits from materializing for a considerable time after project implementation. The increase in competition for land might provide incentives for greater agricultural productivity (target 2.3), which might be further facilitated by tools made of non-timber forest products, such as axe and machete handles, baskets and sieves. Besides, forests can contribute to farmland pollination and seed dispersal through forest-based vertebrate pollinators. An afforested area can also provide fuelwood in proximity to farmland which enables farmers to better dedicate time to their crops by reducing distances for fuelwood collection. These effects as well as shifts in harvest output and non-farm employment remain highly contextual, however. Afforested areas likely contribute to ensuring sustainable food production systems and implement resilient agricultural practices (target 2.4) by providing shelter for critical vertebrate pollinators and diverse genetic material as well as by reducing soil erosion and by acting as a buffer for nitrate leakage.

We identified a few targets with a negative score as part of a range for this project type. With another definition of the project type (e.g., monocultures), the picture likely changes. The only target which is always negatively impacted by afforestation (score -1 to -2) is target 6.4 on water scarcity and efficiency. Although afforestation can have a positive effect on safe drinking water and water quality (targets 6.1 and 6.3), forests need great quantities of water to grow and sustain compared to most crops and other types of vegetation. This negatively affects local **water availability**. The magnitude of the water consumption is nonetheless dependent on factors such as tree species composition and tree density.

A conflict of objective arises when we consider the interaction between afforestation and **affordable and clean energy** (SDG 7). The project definition includes the sustainable harvesting of forest resources. It does not, however, prescribe how the forest resources, such as woody biomass, are ultimately used. Wood, if harvested sustainably, is a renewable resource. From a climate perspective, carbon captured in woody biomass is ideally used as long as possible. Its lifetime should be extended before the wood is used energetically at the end of its life, releasing carbon back into the atmosphere. Thus, the prolonged use of woody biomass (e.g., as furniture or for construction) should usually be prioritized compared to an energetic use (e.g. as fuelwood for cooking). The use of woody biomass as fuelwood can however offer positive impacts under SDG 7. Sustainably harvested fuelwood can provide access to affordable and reliable energy (target 7.1), but it cannot be considered a modern and clean fuel if it is not combined with proper technologies, such as improved cookstoves. Depending on the magnitude of the sustainable harvesting, using fuelwood for cooking can increase the share of renewable energy if households would otherwise use fossil fuels (target 7.2). Therefore, the provision of fuelwood poses a trade-off with the desired carbon sink of the afforested area. This is represented in the low positive scores for these two targets. Additionally, the impact depends on the extent to which (fuel-) wood might be collected from the afforested area and how it might be used (e.g. for cooking or as building material).

In conclusion, afforestation contributes by its nature to targets under SDG 15 on life on land. Moreover, there are many positive impacts on poverty alleviation, food, health and well-being, and water quality. The manifestation and magnitude of these positive impacts depends, however, on the specific design and local context where the project is implemented. Afforestation projects can therefore have multiple benefits beyond GHG emission reduction and removal, but they require a thoughtful design to achieve these desired outcomes. The conflict of objectives between forests as a carbon sink and the benefits of economically using fuelwood and timber is a challenge inherent to this project type.

Table 4: **Sustainable development impacts of afforestation projects**

SDG target	Score	Key findings	Literature sources in addition to expert input
1.1	0 to 2	The contribution of forests to poverty alleviation is highly contextual. However, forests can help people diversify their income, accumulate savings and move out of poverty, e.g. through inclusive approaches like CFM.	Angelsen et al. (2014), Cheng et al. (2017), Miller et al. (2020), Gutiérrez Rodríguez et al. (2016)
1.2	0 to 2		
1.4	1 to 2	Depending on the local implementation and design, a project could include facilitate access to forest resources for the poor and vulnerable households that live nearby.	-
2.1	-1 to 2	While afforested areas might increase pressure on food production systems, if these areas were previously used for agriculture and by hindering agriculture to expand in response to market shifts or climate change and degradation, forest-related food and fuelwood for cooking can benefit local communities. The benefits might be hampered by the long timescales of forest growth.	Vira et al. (2015), Aju (2014), Sunderland et al. (2013), Rowland et al. (2017), Krause and Tilker (2022), Obersteiner et al. (2016)
2.3	1 to 2	The increase in competition for land might give incentives for greater agricultural productivity, which might be further facilitated by tools made of non-timber forest products. Besides, forests can contribute to farmland pollination and seed dispersal and provide fuelwood in proximity to farms. These effects remain highly contextual, however.	Aju (2014), Krause and Tilker (2022), Gutiérrez Rodríguez et al. (2016)
2.4	2	Beyond providing shelter for critical vertebrate pollinators, natural forests feature upmost diverse genetic material which can be utilized for breeding more resilient crops. Furthermore, forests reduce soil erosion and can act as a buffer for nitrate leakage from surrounding agriculture.	Aju (2014), Sunderland et al. (2013), Krause and Tilker (2022)
3.4	-1 to 1	Forests and wildlife have major well-being benefits across different cultural contexts. Therefore, it is critical to permit adjacent community access to forests and culturally important forest products, such as wild meat and medicine. However, forestry accidents could occur if occupational safety regulations are poor.	McFarlane et al. (2019), Krause and Tilker (2022)
3.9	1	Additional tree cover can remove pollutants from air and soil (under specific conditions through phytoremediation). However, a vast number of trees would be needed to be effective on reducing deaths and illnesses.	-
4.2	0	No interaction identified.	-
4.3	0		-
5.1	-1 to 1	Examples of both gender-inclusive projects and patriarchal forest decision-making structures in some communities show that the outcome of afforestation projects on target 5.1 is highly contextual.	Arora-Jonsson et al. (2019), Boyer-Rechlin (2010)

SDG target	Score	Key findings	Literature sources in addition to expert input
6.1	1	By improving stream water quality, forests may reduce the costs of water treatment, thus contributing to safe and affordable drinking water.	Amezaga et al. (2019)
6.3	1 to 2	Afforestation which takes place on agricultural land can improve water quality through avoided fertilization and pesticide use.	Jackson et al. (2005), Amezaga et al. (2019)
6.4	-1 to -2	Compared to other vegetation, forests need great quantities of water to grow and be sustained. Although context-dependent, this poses a trade-off with the benefits of forests on other water-related targets.	Ellison et al. (2017), Amezaga et al. (2019), Ilstedt et al. (2016)
6.6	0	According to our project definition, afforestation takes place on non-forest land, excluding natural biomes, and therefore has no impact on either the restoration or the protection of water-related ecosystems	-
7.1	1	Sustainably harvested fuelwood can provide access to affordable and reliable energy. However, it cannot be considered modern, if not combined with proper technologies, such as ICS. Additionally, the prolonged use of woody biomass (e.g. as furniture) should be prioritized compared to an energetic use from a climate perspective.	-
7.2	0 to 1	Depending on the magnitude of the sustainable harvesting, using fuelwood for cooking can increase the share of renewable energy if households previously used fossil fuels. However, the prolonged use of woody biomass (e.g. as furniture) should be prioritized compared to an energetic use from a climate perspective.	-
7.3	0	No interaction identified.	-
8.3	0 to 1	Income-generating approaches like locally-controlled forest businesses can yield positive impacts. It remains unclear, however, to what extent these concepts are applied in VCM projects.	Macqueen et al. (2020)
8.4	0 to 1	If sustainably harvested wood is used for economically productive purposes, it can slightly contribute to decoupling economic growth from environmental degradation.	-
8.5	0 to 1	Although contextual, afforestation projects can support job creation and employment.	Gutiérrez Rodríguez et al. (2016), Kim et al. (2021)
9.2	0	No interaction identified.	-
9.4	0		-
10.1	1	Poor households may particularly benefit since forests tend to have a more important role for them than for higher income deciles.	Angelsen et al. (2014)
11.1	0 to 1	If combined with incentives for the use of improved wood-based construction materials, there is a weak contribution to improved housing in some areas.	-
11.4	0 to 1	Various cultural values might be enhanced by the afforested areas (target 3.4).	-
11.6	0	No interaction identified.	-

SDG target	Score	Key findings	Literature sources in addition to expert input
12.2	2	The various natural resources generated by afforestation, both timber and non-timber resources such as forest food, are meant to be sustainably managed by our project definition.	-
12.3	0	No interaction identified.	-
12.4	0		-
12.5	0		-
15.1	2	Although not restoring water-related ecosystems (unlike reforestation), afforestation can promote their conservation and sustainable use.	-
15.2	3	Afforestation projects deliver progress on this target by increasing afforestation and the sustainable use of forest resources.	-
15.3	0 to 3	Depending on the area, afforestation can be very effective in stopping and reversing land degradation.	Smith et al. (2013)
15.5	1 to 2	Afforestation helps to conserve and restore biodiversity, depending on the biodiversity in the baseline scenario.	Smith et al. (2013), Kim et al.
15.9	0	No interaction identified.	-

Note: A list with explanations of the targets can be found in Table 9 in the Annex.

4.2 Improved cookstoves

This section presents and discusses the assessment of sustainable development impacts of the project type *improved cookstoves (ICS)*.

This project type is defined as the distribution of improved fuelwood or charcoal cookstoves to households or institutions (e.g. schools), thereby replacing the use of less energy efficient cookstoves. The ICS provide for better combustion and improved heat transfer. The baseline is the use of traditional cookstoves fuelled by fuelwood or charcoal. The ICS rely on the same type of fuel, thus excluding the use of energy crops as fuel or fossil fuels such as liquified petroleum gas (LPG).

Households often practice fuel or stove stacking, a phenomenon of using multiple stove and cooking fuel combinations within the same household. This phenomenon can impair the anticipated effects of implementing ICS projects (Ruiz-Mercado and Masera 2015), e.g. by reducing the desired efficiency gains and emission reductions from ICS. According to Zhang and Ochieng (2020), a major reason for stacking is saving time by cooking more than one meal simultaneously. It was also shown that a larger meal size and thus pot size could only fit on traditional cookstoves and not on ICS. Deploying two-burner ICS can reduce the need for stacking significantly (Zhang and Ochieng 2020). As various cookstoves are deployed in the VCM, we refrain from including the exact design or a single design of ICS (material, portable or fixed, one- or two-burner) in the project definition. Additionally, the monitoring of VCM projects usually considers stacking.

For this project type, positive impacts are identified on 20 targets. The assessment is shown in Table *5*. There is a potential positive impact (see method in section 3) on three additional targets (meaning a range from zero to plus one, two or three). No interaction was identified for 13 out of the 36 targets. Compared to the other project types, ICS positively influence the highest number of targets.

ICS have a clear positive impact on **poverty reduction** (SDG 1) by allowing households to save on fuel expenses and potentially creating job opportunities along the stove value chain (targets 1.1 and 1.2). Additionally, the use of ICS saves time which could be spent on business or other activities. This particularly affects women who typically take care of cooking and collecting fuelwood. These aspects also create a positive impact on targets 8.3 and 8.5 on job creation and decent work.

The use of ICS can also have a strong impact on the targets under SDG 2 on **zero hunger**. Since fuelwood collection and charcoal production can have massive environmental impacts, such as land degradation and loss of watershed functions, reducing biomass consumption takes pressure from agricultural systems, thereby increasing food security (target 2.1). Moreover, the use of ICS can lead to more nutritious meals through improved cooking practices and an increase in the time available for preparing meals. The reduced pressure on agricultural systems through reduced biomass consumption for cooking also helps to increase agricultural productivity (target 2.3).

The **health benefits** of ICS are often promoted as their core positive impact on sustainable development (SDG 3 on good health and well-being) since household air pollution (HAP), which is mainly caused by traditional cookstoves, is a major cause of respiratory diseases, such as pneumonia and lung cancer as well as strokes and heart diseases, among others. Although ICS can lower particulate matter and CO concentrations by more than 50% compared to traditional three-stone open fire cookstoves (Pope et al. 2017), studies show that the level of HAP achieved by ICS is still well above the recommendations by the World Health Organization (WHO) (Mazorra et al. 2020; Amegah and Jaakkola 2016; ESMAP 2015). Target 3.9 focuses on "substantially reduc[ing] the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination" (Table 9). As the decline in HAP levels from ICS is not sufficient to meet WHO recommendations, the literature reveals that the exposure of affected households is still too high to significantly reduce the number of HAP-related deaths and illnesses. Clean fuels such as electricity, LPG and biogas appear to be more capable and cost-effective in addressing target 3.9. The project type thus scores plus 2 on this target.

The positive impacts for nutrition and - to a smaller extent - HAP in turn create a potential positive impact on

childhood development and education (targets 4.2 and 4.3) as ICS could facilitate the development of children by preparing nutritious meals and snacks and reducing HAP, albeit not to the desired degree. If the workload (fuel collection and cooking) for women and children is reduced, they might suffer less from fatigue which in turn could lead to higher attendance in school and facilitates learning.

A very important impact of the project type is the one concerning **gender equality and empowering women** (SDG 5). The responsibility as well as the associated risks of collecting fuel, feeding stoves, and cooking typically falls on women and girls. Women spend several hours a day on collecting fuelwood and cooking, meaning that they have little time to take part in any other activities. Time savings from collecting fuel and cooking enable women to spend more time caring for children, increase their ability to pursue income generating and educational opportunities, and/or leadership roles. The use of ICS reduces the time of women spent on cooking and thereby facilitates progress on gender equality and ending discrimination (target 5.1). Furthermore, as women are the main users of cookstoves, they would benefit the most from reduced health risks.

The deployment of ICS has a direct positive impact on the goal of affordable and clean energy (SDG 7) as ICS are more energy efficient than traditional cookstoves. The project type thus increases the global rate of improvement in **energy efficiency** (target 7.3).

The collection of fuelwood and production of charcoal can lead **to deforestation and forest degradation** at the local level. By requiring less fuel input, ICS deployment reduces the pressure on forest ecosystems and thereby contributes to achieving progress on the relevant targets under SDG 15 (life on land), namely 15.1, 15.2 and 15.3.

To summarize, ICS projects potentially have various positive impacts on sustainable development. While ICS clearly contribute to energy efficiency, they also positively impact livelihoods and reduce deforestation and degradation of forest. The switch to ICS from traditional cookstoves significantly lowers the levels of HAP; however, the remaining level of HAP is still above WHO recommendations. A major uncertainty for the SDG impacts is the behavioural change over time regarding stacking. This is further discussed in section 4.5.

Table 5: **Sustainable development impacts of ICS projects**

SDG target	Score	Key findings	Literature sources in addition to expert input
1.1	2	ICS enable users to cut their expenses on fuelwood/charcoal and free up funds for other needs, though it is likely still costlier than consuming modern fuels. Furthermore, there can be new income opportunities along the stove value chain.	García-Frapolli et al. (2010), Bensch and Peters (2015), Aemro et al. (2021), Karanja and Gasparatos (2019)
1.2	2		
1.4	1	ICS can provide the basic service of energy security to households that depend on traditional energy carriers. While this benefits all household members, it particularly helps poor women.	Karanja and Gasparatos (2019)
2.1	3	Since fuelwood collection and charcoal production can have massive environmental impacts, such as land degradation and loss of watershed functions, reducing biomass consumption takes pressure from agricultural systems, thereby increasing food security. Moreover, the use of ICS can lead to more nutritious meals through improved cooking practices.	Karanja and Gasparatos (2019), Muller (2009)
2.3	3	Taking pressure from agricultural systems (target 2.1), reduced biomass consumption can increase agricultural productivity.	Karanja and Gasparatos (2019)
2.4	0 to 3	If ICS reduce the amount of crop wastes gathered as biomass fuel, this waste can be plowed back as organic manure instead, thereby enhancing soil quality compared to the baseline.	
3.4	3	Reducing the amount of fuelwood needed, ICS make users less prone to diseases related to fuelwood collection such as musculoskeletal damage.	WHO (2021)
3.9	2	ICS significantly reduce the level of HAP. However, levels of air pollution of ICS are still considered higher than WHO recommendations.	Pope et al. (2017), Schilmann et al. (2019), Rosenthal et al. (2018; Amegah and Jaakkola), Amegah and Jaakkola (2016), Mazorra et al. (2020), Hanna et al. (2016), Kammila et al. (2014), World Health Organization (2016), Vivid Economics (2019)
4.2	0 to 2	ICS might facilitate the preparation of nutritious meals and snacks for proper development of the children. Reduced indoor air pollution also benefits young children.	Dherani et al. (2008)
4.3	0 to 1	Decreasing the workload of women and children (fuel collection and cooking) might lead to higher school attendance in some cases and less fatigue, which then facilitates learning.	Kelly (2018)
5.1	2 to 3	The responsibility of collecting fuel, feeding stoves, and cooking mostly falls on women and girls. They therefore benefit from the use of ICS through a reduction of time poverty, a reduction of health risk, and potential job opportunities.	Mazorra et al. (2020), Aemro et al. (2021), Romieu et al. (2009), Karanja and Gasparatos (2019), Shankar et al. (2014)
6.1	0	No interaction identified.	

SDG target	Score	Key findings	Literature sources in addition to expert input
6.3	0		
6.4	0		
6.6	1 to 2	Reducing the amount of biomass needed can have a positive impact on forests that act as water catchments.	Karanja and Gasparatos (2019)
7.1	1 to 2	ICS can contribute to a better energy security of households that depend on traditional energy carriers by reducing the amount of fuel needed and its expenditures.	Karanja and Gasparatos (2019), Sagbo (2014), Vivid Economics (2019)
7.2	0	The use of ICS does not increase the share of renewable energy - although ICS can be integrated with other forms of renewable energy at household and community level.	
7.3	3	ICS are more energy efficient than traditional cookstoves.	Bensch and Peters (2015), Aemro et al. (2021), García-Frapolli et al. (2010)
8.3	2	There can be many job opportunities along the stove value chain, which might be curbed by imported cookstoves crowding out local producers, however. The use of ICS saves time which can be spent on other business activities.	Karanja and Gasparatos (2019), Karhunmaa (2016)
8.4	3	By using less fuelwood or charcoal, ICS increase the resource efficiency of consumption.	Bensch and Peters (2015), Aemro et al. (2021), García-Frapolli et al. (2010)
8.5	2	There can be job opportunities along the stove value chain with salaries potentially above the minimum wage. The use of ICS saves time which can be spent on other business activities.	Karanja and Gasparatos (2019)
9.2	0	No interaction identified.	
9.4	0		
10.1	1	ICS can improve economic opportunities, especially within communities in low income, resource-dependent, and rural regions.	
11.1	0	No interaction identified.	
11.4	0		

SDG target	Score	Key findings	Literature sources in addition to expert input
11.6	1	By applying ICS in communities, outdoor air pollution can be reduced at community level.	World Health Organization (2016), Smith et al. (2014)
12.2	3	By using less fuelwood or charcoal, ICS contribute to a more efficient use of natural resources.	Bensch and Peters (2015), García-Frapolli et al. (2010)
12.3	0	No interaction identified.	
12.4	0		
12.5	0		
15.1	0		
15.2	2 to 3	The use of ICS reduces pressure on forests and thus reduces deforestation rates.	Sovacool (2012), Vivid Economics (2019), Karanja and Gasparatos (2019), Amegah and Jaakkola (2016), Bailis et al. (2015)
15.3	2	The use of ICS reduces pressure on forests and thus helps to reduce land degradation.	Sovacool (2012)
15.5	2	By reducing pressure on forests, the project type helps to reduce deforestation and thus benefits natural habitats and biodiversity.	Karanja and Gasparatos (2019), Giam (2017), Allnutt et al. (2008)
15.9	0	No interaction identified.	

Note: A list with explanations of the targets can be found in Table 9 in the Annex.

4.3 Off-grid PV

This section presents and discusses the assessment of sustainable development impacts of the project type *off-grid PV*.

This project type includes the provision of small-scale off-grid PV installations to individual households for electricity generation (for lighting, battery charging or powering small appliances like televisions). It is assumed that the PV installation includes battery storage. A maintenance service by local technicians is included. These small-scale installations replace the use of fossil fuels, such as kerosene-based or LPG lamps, candles or battery-driven lamps.

We do not consider the impacts of the production of PV modules as this would significantly add to the complexity of the assessment. The production of PV modules can have negative impacts on the environment and humans through the conditions at the extraction site for rare earths etc., such as environmental pollution, water use, risk of child labour and other risks. Potential negative of an inappropriate disposal of PV modules is, however, included in the analysis and discussed below in relation to SDG 12.

Overall, 15 positive sustainable development impacts are identified with off-grid PV projects. A further three are only potentially positive impacts (see ranges in Table *6*). Except for target 12.4, no potential negative impacts can be identified. The project type does not have any significant impact on 18 of the 36 targets.

Even though no major direct economic benefit or income generation can be expected, off-grid PV helps the poorest to **save on fossil fuels,** like LPG, batteries or candles. This positive impact on the goal of no poverty (SDG 1) within targets 1.1 and 1.2 might by hampered by potential debt traps if finance models are not adapted to the situation of the (rural) poor. What financial models are used to deploy the installations lies beyond the scope of the project type definition. It is assumed, however, that well-designed off-grid PV projects would take this into account or that installations are subsidized with revenues from the carbon credits. In addition, the literature suggests that income generation impacts are negligible. Therefore, the implementation of an off-grid PV project only enables progress on target 1.1 and 1.2 on poverty alleviation, which leads to a plus one result according to Table 2.

The project type definition includes the creation of maintenance jobs, even though it does not specify the number of jobs created or who gets employed. The project type thus has a positive impact on target 8.3 which concerns job creation, entrepreneurship, and the formation of businesses. There might be an additional positive but rather indirect impact on **business activity** as the distribution of off-grid PV installations within a village increases the access to electricity which makes charging cell phones and running a television (TV) easier. With technical devices becoming more common in rural areas globally, new business models can emerge, such as the provision of mobile payment services, data packages and charging services at local shops and maintenance tasks for cell phones and TVs. Direct solar energy entrepreneurship might be unlikely, however, as most components are imported and off-grid PV installations might be set-up by external professionals. Any potential job creations through the project type need to be compared with the baseline situation where jobs in the candle or LPG industry exist. The project might reduce the number of jobs in those industries depending on how many households switch to off-grid PV in a certain area. Overall, the net effect is considered to be positive, which results in a varied positive impact on target 8.3 depending on the economic activity stimulated.

The major impact of off-grid PV projects on health mainly results from replacing unsafe household light sources. The use of the latter is associated with various risks, such as burns, accidental injuries, and ingestions. Thus, instead using electricity from off-grid PV **improves health and well-being** (SDG 3) in terms of non-communicable diseases (target 3.4). Raising awareness through greater connectivity to TV or access to the internet via charged smartphones (see above) may further contribute to lowering the prevalence of diseases. This additional effect assumes a behavioural change in relation to how the electricity is used. Kerosene-based lighting can have detrimental effects on health and is a source of HAP whereas the use of dry-cell batteries can truly in lead-poisoning if accidentally ingested (e.g. by children) or through contact with contaminated surfaces (if batteries are not disposed properly). While off-grid PV can substantially reduce baseline-related health risks from air and soil pollution (target 3.9), it can itself harm human health in different ways if not disposed appropriately (see below).

Electricity provided by the off-grid PV installation might **empower women** and thus contribute to the gender equality goal (SDG 5). If women have access to electricity, it is likely that they attain access to new information and educational resources (like the TV or smartphones), which in turn might increase their chances of obtaining employment and might empower them. This depends, however, on women's involvement in the decision-making process on the use of the electricity. The literature indicates that women often have less power than men in deciding how the electricity is used. Careful design of off-grid PV projects - and including women in the design process - can help to make progress on target 5.1. Furthermore, it is indicated that women can outperform men in selling energy products, which would make it attractive to offer them entrepreneurial and employment opportunities in such projects.

An important finding for off-grid PV project types is the **trade-off between the price and the quality of solar modules** affecting the goal of affordable and clean energy (SDG 7). Target 7.1 addresses "universal access to affordable, reliable and modern energy services" (Table 9). It is unlikely that off-grid PV can deliver all these aspects at the same time. Low-quality and inexpensive installations are more affordable and thus accessible for a larger number of people. High-quality installations might be more expensive but offer a more reliable energy service. The quality of off-grid PV installations likely impacts its lifetime and repairability, thus influencing targets 12.4 and 12.5. Additionally, the aspect of "universal access" in target 7.1 is further influenced by the distribution of off-grid PV installations within a given community. Existing power structures might be reproduced if those persons within a community receive installations which already have more power than others (e.g. the chief of a village). As a consequence, the access and the benefits (e.g., less money spent on fossil fuels) might not be distributed fairly, which further limits the positive impact of the project type on target 7.1.

Another important aspect is the **recycling and disposal** of solar installations compared to the waste generated in the baseline (responsible consumption and production - SDG 12). Dry-cell batteries are often simply disposed in backyard holes and can thereby severely pollute the environment and harm humans (see health impacts). The use of off-grid PV can therefore reduce or avoid the unsound disposal of dry-cell batteries. In addition, batteries connected to the installation last longer than dry-cell batteries. This results in a very positive impact on target 12.4 (environmentally sound management of chemicals and all wastes throughout their life cycle). The positive impact is though challenged by the recycling and disposal of the off-grid PV installation itself and the batteries used for storage. If not appropriately recycled or disposed, the implementation of an off-grid PV might even lead to a negative outcome compared to the baseline as this can result in major harmful effects on human health and the environment, such as lead-poisoning, skin burns and soil acidification.

Compared to target 12.4, target 12.5 does not focus on harmful chemicals but the waste hierarchy. The use of off-grid PV avoids the waste generated from dry-cell batteries. Where VCM projects are implemented, it is very likely that there is no recycling system for batteries in place. Although context-dependent, presumable deficits in the repair, re-use and recycling of off-grid PV installations hamper the positive impact on target 12.5, resulting in a range for this target in Table 6 .

To conclude, off-grid PV projects might have a range of positive impacts on sustainable development besides an increase in renewable energy supply. The trade-off between the price and the quality of the installations needs to be kept in mind when assigning SDG impacts. A cause of uncertainty is the recycling potential and the end-of-life management of the installations which highly depends on the local context. Furthermore, to reap potential benefits for sustainable development, project designs need to account for existing power structures within households (target 5.1) but also within a community (target 7.1).

Table 6: **Sustainable development impacts of off-grid PV projects**

SDG target	Score	Key findings	Literature sources in addition to expert input
1.1	1	Solar off-grid installations help to save on fossil fuels for electricity generation and thus help to alleviate poverty. Depending on the system used and finance model deployed, this slightly positive impact might be compensated by potential debts from acquiring the installation.	Stojanovski et al. (2017), Feron (2016), Grimm et al. (2016), Rahman and Ahmad (2013)
1.2	1		
1.4	2	Electricity through solar power enables/improves the user's access to technology such as televisions and cell phones with the latter allowing in turn the use of mobile payment services. However, the access and the use of these technologies and basic services might be unequal within one household or within one community (target 10.1).	Shammin and Haque (2022), Stojanovski et al. (2017), Kizilcec and Parikh (2020)
2.1	1	The access to electricity through solar power can improve a meal's nutritional quality since situations in which cooking must be hastily done in an environment of insufficient light can be avoided.	Asaduzzaman et al. (2013)
2.3	0	No interaction identified.	-
2.4	0		-
3.4	3	Replacing unsafe household light sources, solar off-grid installations have the potential to avoid the risk of burns, accidental ingestions, and compromised visibility. Awareness raising through greater connectivity to television (target 1.4) may further contribute to lowering the prevalence of diseases.	Mills (2016), WHO (2021), Kizilcec and Parikh (2020)
3.9	2-3	Replacing unsafe household light sources, solar off-grid installations have the potential to avoid the risk of HAP from kerosene combustion and lead poisoning from batteries. However, there is a risk that unsafe disposal of solar installation might contaminate water and soil.	Mills (2016), Ortega et al. (2021), Manhart et al. (2018), World Health Organization (2016)
4.2	2	The lighting provided by the solar installation promotes the health of children as HAP is avoided and provides more reliable and better lighting for children to study.	Vivid Economics (2019), Bisaga (2019), Kizilcec and Parikh (2020)
4.3	0	No interaction identified.	-
5.1	1	Electricity provided by the solar installation might give women access to new information sources (e.g. TV) facilitating education and empowerment. This depends, however, on women's involvement in the decision-making process as regards the use of the electricity. Furthermore, it is indicated that women can outperform men in selling energy products, which would make it attractive to offer them entrepreneurial and employment opportunities.	Asaduzzaman et al. (2013), Olubayo and Oguegbu (2020), Winther et al. (2018), Feron (2016), Pueyo (2020)
6.1	0	No interaction identified.	-

SDG target	Score	Key findings	Literature sources in addition to expert input
6.3	0		-
6.4	0		-
6.6	0		-
7.1	2	While the provision of solar off-grid installation clearly contributes to 7.1, there is a trade-off between the price (universal access and affordability) and the quality of installations (reliability). Existing power structures within communities might be reproduced in terms of the access/use of solar off-grid installations and fuel saving benefits.	Groenewoudt et al. (2020)
7.2	3	Significantly reducing the consumption of kerosene, candles and batteries, solar off-grid installations can elevate the share of renewable energy.	Stojanovski et al. (2017), Grimm et al. (2016), Asaduzzaman et al. (2013)
7.3	0	There is no clear interaction here as the energy efficiency depends on the technological composition of the solar module and the energy efficiency of the devices used in the baseline.	Imu et al. (2021)
8.3	1 to 2	Maintenance jobs are created (project definition). Indirectly, business activity can be facilitated or created (e.g. providing charging for appliance for cell phones, thus enabling mobile payment services). Direct solar energy entrepreneurship might be hampered as most components are imported.	Shammin and Haque (2022), Feron (2016), IRENA (2018), Groenewoudt et al. (2020)
8.4	0 to 1	The resource efficiency of a PV system depends on its materials and the product lifetime but might perform better compared to the baseline.	Gervais et al. (2021), Bisaga et al. (2021)
8.5	1 to 2	Same justification as target 8.3.	IRENA (2018), Groenewoudt et al. (2020)
9.2	0	There is no impact on a large scale in terms of expected industry.	-
9.4	0		-
10.1	0 to 1	If maintenance jobs are given to the local population (target 8.3), there might be a positive impact.	-
11.1	2	Replacing unsafe household light sources, solar off-grid installations make living environments generally safer (targets 3.4 and 3.9). However, there are specific safety risks related to the system's batteries. While it is primarily rural areas benefiting, solar off-grid installations can also serve informal urban settlements without grid connection.	Bisaga et al. (2021), Manhart, A. and Latt, K. and Hilbert, I. (2018)
11.4	0	No interaction identified.	-
11.6	0		-

SDG target	Score	Key findings	Literature sources in addition to expert input
12.2	0	The efficient use of materials depends on the lifetime of the installation and how it is taken care of. As this assessment is not including the time dimension and as the impact depends on the design of the project, the interaction cannot be properly considered here.	Gervais et al. (2021)
12.3	1	If the solar off-grid installation used is powerful enough, small fridges or other food storing appliances might be powered and thus potentially reduce food waste.	-
12.4	-3 to 3	While reducing the unsound disposal of dry-cell batteries, solar off-grid installations and their batteries need to be dis-posed/recycled safely as well, otherwise they cause harmful effects on human health and the environment.	Grimm et al. (2016), Manhart et al. (2018), Feron (2016)
12.5	-1 to 1	Solar off-grid installations reduce the waste generated in the form of dry-cell batteries in the baseline. However, the re-pair, re-use and recycling of solar systems and PV batteries is highly contextual.	Stojanovski et al. (2017), Manhart, A. and Latt, K. and Hilbert, I. (2018), Cross and Murray (2018), Bisaga et al. (2021), Groenewoudt and Romijn (2022)
15.1	0	No interaction identified.	-
15.2	0		-
15.3	0		-
15.5	0		-
15.9	0		-

Note: A list with explanations of the targets can be found in Table 9 in the Annex.

4.4 Water filters

This section presents and discusses the assessment of sustainable development impacts of the project type *water filters*.

Water filter projects are defined here as projects that deploy point-of-use water filters at household level, which allow purification of water in rural areas with no water supply network in place. Water filters are typically designed as hybrid filtration systems which comprise multiple layers. Our project type definition compromises ceramic filters (impregnated with nanoparticles of silver or copper) with an activated carbon cartridge, since these components are commonly deployed by VCM water filter projects.

In calculating emission reductions from VCM projects, carbon crediting programs usually allow projects to assume that, in the baseline, participant households boil their water for disinfection purposes or start to do so in the future. This assumption - referred to as a 'suppressed demand' baseline - allows these projects to claim significant emission reductions from avoided burning of non-renewable biomass or fossil fuels. In practice, however, projects implemented in the VCM often take place in regions which include households without any resources to treat water at all. By contrast, the concept of 'suppressed demand' baselines assumes that - once the region has progressed to a higher level of development - all households would switch to the practice of boiling water. Consequently, it is argued that including those households which lack access to water treatment for resource reasons in the project's emission reduction calculations is justifiable in order not to wait until the additional emissions occur but to prevent them in the first place.

The assumed baseline scenario also greatly affects sustainable development outcomes, albeit in totally different ways: many sustainable development benefits only occur if the water is not disinfected in the baseline scenario. We therefore split the following assessment by separately scoring the application of water filters compared to the practice of boiling water (Table *8*, column 2) and compared to a situation in which water is not treated at all (Table *8*, column 3). This allows us to be more precise in describing the baseline-specific impacts of the project type on the selected SDG targets (Table *8*, column 4).

It should be noted that the global demand for bottled water as another source of affordable safe drinking water is rising quickly (Cohen and Ray 2018). Although there are GHG emissions linked to the production and transportation of bottled water, they are much lower than the emissions associated with boiling water. This potential baseline scenario is not considered in VCM methodologies. Therefore - and in order to reduce the complexity of the assessment - we do not consider this scenario.

Similarly to the matter of stove stacking in ICS projects (section 1.1), it is crucial that water filters are used as the predominant water purification tool and over a long-term period for both GHG mitigation and sustainable development outcomes to materialize. Again, as the monitoring of VCM projects incorporates changes in filter adoption and use patterns over time, we do not consider the time dimension of the project type, thereby reducing contextuality.

One limitation of the following assessment is the scarce availability of literature on water filters and their contribution to sustainable development. Although they are the subject of increasing interest, water filter projects to date do not come close to the relevance of our other three project types within the context of the VCM, which might explain the unsatisfactory quantity of literature at hand. To strengthen the foundation of our scoring, the assessment of this section will be based on the official documents of six selected VCM water filter projects as a third component, complementary to the expert input and the limited evidence retrieved from the literature.

We selected these projects from the Gold Standard since this is the only larger programme which both envisages the documentation of SDG contributions and incorporates water filter projects. We identified the six projects through a key word search of 'water filter' and 'filtration' in the relevant project type categories in the Gold Standard Impact Registry[7]. Among the 20 projects identified, we selected the six projects characterized in

[7] Gold Standard Impact Registry: https://registry.goldstandard.org

Table 7, with the aim of covering different geographic locations, project scales and credit periods. The limitation of this approach is that its findings must be regarded as indicative only since the projects might not entirely match our project definition with regards to filter composition.

Table 7: **Overview of selected water filter projects**

Gold Standard ID	Country	Scale	Crediting period start
1332	Honduras	Micro-scale	Aug 04, 2012
2095	Lao PDR	Small-scale	Jul 16, 2019
4290	Indonesia	Small-scale	Mar 01, 2014
5796	Haiti	Micro-scale	Jan 01, 2015
7571	Uganda	Micro-scale	Apr 01, 2019
11207	Kenya	Large-scale	Oct 09, 2020

Source: Gold Standard Impact Registry: https://registry.goldstandard.org

For this project type, we have identified eight (eleven) positive or potentially positive impacts of the project type against the baseline of boiled water (untreated water). Only for target 12.5, negative implications might arise. Regarding target 3.9 - and target 6.1 when comparing to boiled water - the impact can go in either direction. The project type does not have any significant interaction with 25 (23) of the 36 targets against the baseline of boiled water (untreated water).

The wide ranges of scores on target 3.9 reflect that there are various effects to consider in terms of the health benefits from reduced pollution (SDG 3). **Compared to boiling water**, it must be noted that ceramic filters have their strengths and weaknesses as they enable their users to also remove solid contaminants such as iron, nitrates and microplastics but cannot protect from viruses to the degree that boiling does. It is therefore necessary to know which water-borne contaminants are locally present to determine whether water filters are preferable to boiling water. The range further extends to plus 2 for reducing smoke levels in the kitchen whereas the negative end of the range of minus 2 also accounts for concerns about arsenic traces leached out of ceramic filters.

If the affected households relied on **untreated water**, the relative improvement of water quality is more distinct as water is utterly unsafe in the baseline. Consequently, the significant improvement is reflected in the monitoring reports of the single projects revised, which determine a great number of households reporting a reduction of water-borne diseases. The only negative effect compared to untreated water is the above-mentioned arsenic leakage which might emerge from some ceramic filters, potentially causing serious health issues. Thus, the score ranges from minus 1 to plus 3.

Interestingly, the projects GS5796 and GS1332 (Table 7) report that the households they have supplied with filters perceived both a 100% reduction of smoke levels and a 100% reduction of water-borne diseases, thereby claiming impacts against both baselines at the same time, which appears contradictory.

Regarding gender equality and women empowerment (SDG 5), there are indications of water-related projects benefitting from women engagement, which might in turn benefit women from additional entrepreneurial and employment opportunities. Since it is particularly women who are responsible for fuelwood collection and cooking, **replacing water boiling** also helps to reduce women's time poverty. However, the fuelwood reduction from implementing water filters alone cannot be significant enough to fundamentally alleviate women's time poverty, though this might change when accompanied with the implementation of an improved cookstove. Thus, target 5.1 bears a score of plus 2, regardless of the baseline.

The evident but relatively small fuelwood savings also affect other targets, most importantly **resource efficiency** (target 12.2), which therefore brings about a score of plus 1. Although positive influences can be expected for the targets 6.6 (protection of water-related ecosystems), 8.4 (decoupling economic growth from environmental degradation) and the forest-related targets under SDG 15 (life on land), we cannot deem the small savings as significant enough to benefit whole ecosystems or - with regards to 8.4 - influence the character of the overall economy. Therefore, no substantial interactions with these targets are identified.

In conclusion, it should be noted that water filter projects, as defined in this paper, have by far the fewest interactions or impacts with the selected SDG targets. Where there are impacts, they are often context-dependent and consequently lead to varying scores, which is especially true for target 3.9. If replacing boiling practices, water filters can lead to fuelwood savings - which are, however, less significant as for ICS. Finally - and most importantly - it must be emphasized that the impact of the project type on some targets depends highly on the underlying baseline.

Table 8: **Sustainable development impacts of water filter projects**

SDG target	Score - boiled water	Score - untreated water	Key findings	Literature sources in addition to expert input
1.1 1.2	2	0 to 1	The deployment of water filters **replacing water boiling** entails significant monetary savings from reduced fuelwood consumption. Furthermore, communities can potentially escape poverty by crafting and selling ceramic filters. However, in reality, many of these filters are crafted and sold by large companies, which would not directly benefit the income of poor communities.	GS (2019b; 2020b)
1.4	0	2	**Compared to untreated water**, the use of water filters directly benefits the access of poor communities to basic water services. Using filters, they can also better manage the water resources available to them.	-
2.1	0	1	**Replacing untreated water**, water filters can reduce water-borne diseases (see target 3.9), which may trigger enteric dysfunction, i.e. the malabsorption of nutrients. Thus, treating water can avoid undernutrition.	UN Water (2018)
2.3	0	0	No interaction identified.	-
2.4	0	0		-
3.4	0	0		-
3.9	-2 to 2	-1 to 3	Water filter projects refer to high user numbers reporting a reduce in water-borne diseases (if they used **untreated water before**), coughing, itchy eyes and smoke levels in their kitchen (if they **boiled water before**). Boiling water and using water filters can affect water quality in different ways depending on the local conditions. There are also indicators of arsenic traces leached out of ceramic filters.	WHO (2019), Clasen et al. (2015), Wolf et al. (2014), Hutton and Chase (2016), GS (2019a; 2020a; 2020b)
4.2	0	1	There are links between diarrhoea – a water-borne disease – and children struggling with nutrient malabsorption. Thus, early childhood development can benefit from water filters **replacing untreated water**. Furthermore, the reduction of water-borne diseases could improve school attendance in some contexts.	Hutton and Chase (2016)
4.3	0	1	The reduction of water-borne diseases **from untreated water** could improve school attendance in some contexts.	Hutton and Chase (2016)
5.1	2	2	There is evidence that water-related services can be more effective when women have an active role in implementation and operation. This endows them with various entrepreneurial and employment opportunities. Since it is particularly women who are responsible for fuelwood collection and cooking, **replacing water boiling** also helps to reduce women's time poverty and thereby creates opportunities for occupational engagement.	Fisher (2006), Mazorra et al. (2020), Aemro et al. (2021)

SDG target	Score - boiled water	Score - untreated water	Key findings	Literature sources in addition to expert input
6.1	-2 to 1	2	**Compared to boiling water**, the filtration technologies commonly used by VCM projects can have both advantages, such as solid contaminant removal, and shortcomings, such as declining effectiveness and viruses bypassing the filtration. For households, which have previously relied on **untreated water**, filters can improve access to drinking water.	UN Water (2018), WHO (2019), WHO (2017), WHO (2018), GS (2022; 2019b; 2020b; 2021)
6.3	0	0	No interaction identified.	-
6.4	0	0		-
6.6	0	0		-
7.1	0	0		-
7.2	0	0		-
7.3	1	0	Water filters can increase energy efficiency by reducing the practice of **boiling water**. However, the fuelwood savings are relatively small (especially compared to savings from ICS).	-
8.3	0 to 1	0 to 1	There can be job opportunities connected to water filter projects. However, in reality, many of these filters are crafted and sold by large companies.	Karhunmaa (2016)
8.4	0	0	No interaction identified.	-
8.5	0 to 1	0 to 1	See 8.3.	GS (2019a; 2019b; 2020a; 2020b; 2021)
9.2	0	0	No interaction identified.	-
9.4	0	0		-
10.1	0 to 1	0 to 1	If the potential for job creation comes about (see 8.3), the bottom 40% of the population could particularly benefit.	-
11.1	0	0	No interaction identified.	-
11.4	0	0		-
11.6	0	0		-

SDG target	Score - boiled water	Score - untreated water	Key findings	Literature sources in addition to expert input
12.2	1	0	Water filters **replacing boiling practices** can increase resource efficiency by reducing the demand for fuelwood. Consider-ing the amount of fuelwood needed to boil water, the impact is relatively small (e.g. compared to ICS).	GS (2021)
12.3	0	0	No interaction identified.	-
12.4	0	0		-
12.5	-1 to 0	-1 to 0	Depending on the filter type and its components, it might not be practicable to re-use or recycle the water filters after their lifetime.	-
15.1	0	0	No interaction identified.	-
15.2	0	0		-
15.3	0	0		-
15.5	0	0		-
15.9	0	0		-

Note: A list with explanations of the targets can be found in Table 9 in the Annex.

4.5 Contextual aspects and cross-cutting findings

Overall, sustainable development impacts are highly contextual. Individual project designs differ as well as the local conditions in different countries. The results of the assessment therefore depend on the individual circumstances of projects. Aspects which affect the robustness of the findings are, for example, biophysical circumstances (such as local climate, water availability, proximity of villages to afforested area), governance (like national targets/programs), or vulnerability (such as risks to afforested areas, livelihood needs).

Furthermore, sustainable development impacts might vary throughout time. For example, the use of ICS and water filters is dependent on behavioural change. Their use might decline over time, if they are not suited to the needs of the households, resulting in an increase of stove stacking or the return to traditional cookstoves (see section 1.1). Expected SDG impacts might vanish in the long run if this is not accounted for. The time-dimensional aspect also concerns the other project types. In the case of solar off-grid installations, the efficient use of materials crucially depends on the lifetime of the installation and how it is taken care of. Likewise, as there is a lack of evidence regarding the disposal of off-grid solar systems - since they have often been installed recently and are therefore usually still in use - sound disposal remains an open question. Forests in turn take time to grow and build up a carbon sink. Thus, also the ecosystem services related to afforested areas do not materialize from the beginning. Risks to the GHG removal potential of afforested areas, e.g. through fires, also affect related sustainable development impacts. The time dimension is, however, beyond the scope of this assessment due to its complexity and uncertainty. Potential changes over time are ideally monitored in carbon credit projects and accounted for in quantification methodologies. The time-dimensional aspect should also be taken into account more thoroughly in program methodologies to evaluate SDG impacts.

The following methodological issues also pertain to all project type assessments:

Firstly, from the literature review and the input from the experts it became evident that impacts on SDG 9 (industry, innovation and infrastructure) are mainly relevant for industrial-scale projects. For none of the four assessed project types, the impact was identified as significant enough to deliver progress on targets 9.2 and 9.4. Therefore, these targets receive a score of zero for all project types. Any future assessment using the method applied here might only include these targets for large-scale VCM projects (e.g. hydro power).

Secondly, target 15.9 on "integrat[ing] ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts" also does not seem relevant for VCM projects. The target concerns the establishment of public national or local programs and targets. While VCM projects may contribute to any existing national targets, it is unlikely that VCM projects trigger the establishment of such targets. Future evaluations following the method of this paper might refrain from including this target in the analysis.

Thirdly and more broadly, we acknowledge that the impacts identified for a particular SDG target can partly depend on our underlying interpretation of this very target, which in turn might deviate from what the wording of the higher-level SDG or the lower-level target indicators suggest. For example, since we have generally taken the SDG targets as our point of reference, we did not assign afforestation projects an interaction with target 6.6, which calls for the protection and restoration of water-related ecosystems, including forests. As, according to our project definition, afforestation takes place on non-forest land, it has no impact on either the protection of present water-related ecosystems or the restoration of former ones. Although the fact that afforestation is going to create new water-related ecosystems cannot consequently be considered as an impact on target 6.6, this would have been different if we had based our SDG target interpretation on the respective target indicators. Then, afforestation would have achieved a positive score on the same target since the indicator 6.6.1 only measures the general "change in the extent of water-related ecosystems" (United Nations 2015a), which would have been positively influenced by planting new forests.

A further challenge of assessing sustainable development outcomes at the SDG target level is the distinction between single targets. On the one hand, there are targets which only seem to specify others while still addressing the same problem. This is especially the case for target 15.2, which calls for promoting forests and thus can be considered as a means to achieving target 6.6 (the protection and restoration of water-related ecosystems). Also, the targets 6.1 (access to safe and affordable drinking water) and 7.1 (access to affordable, reliable and modern energy) can be regarded as key elements of what target 1.4 demands - the rights to economic resources and the access to basic services. On the other hand, we face imprecise distinctions between the targets 8.4 and 12.2, which both deal with resource efficiency in consumption and production, and the targets 1.1., 1.2, 8.3 and 8.5, all of which intend to tackle poverty and livelihood issues.

Finally, a potential shortcoming is that the literature is mostly not specifically related to the VCM but assesses the impacts of the respective technology or practice more broadly and may use different assumptions regarding the baseline scenario. For example, our assessment of the impact of ICS on target 3.9 draws on literature which deals with the general capability of ICS to reduce HAP, regardless of whether the ICS were implemented in the context of the VCM. It is conceivable, however, that the context of the project implementation affects the extent to which HAP is reduced through the choice of the model of the new cookstove and its quality, or through the selection of the beneficiary households. In the case of ICS, we have partly based our literature findings on cookstove interventions by non-governmental organizations (NGOs) and public development programs, and on experimental interventions, such as Randomized Control Trials (RCTs), which try to imitate the settings of real interventions. To avoid potential biases arising from this, we took two corrective measures. Firstly, we excluded aspects which obviously apply to non-VCM contexts only, and secondly, we discussed critical questions with the experts, who helped to put our literature findings in the relevant context.

5. Conclusions and recommendations

The results of our assessment show that all the selected project types clearly have positive sustainable development impacts beyond GHG emission reductions. Positive impacts were identified for one third to about half of the 36 analyzed SDG targets, depending on the project type. Interestingly, we identified only a few negative scores. The majority of these negative scores might only apply in certain contexts - which is indicated by the given ranges. For example, off-grid PV projects might negatively impact target 12.4 (environmentally sound management of chemicals and all wastes) if solar installations are inappropriately disposed or recycled at the end of their life. We could not identify significant impacts from water filter projects on over half of the targets. For the other three project types, no interactions could be identified for about one third of targets respectively.

Sustainable development impacts are, however, difficult to generalize. A key finding of the analysis is that sustainable development impacts are highly contextual. Generalized impacts identified in this report might vary for individual projects in different local contexts. This holds in particular for afforestation projects: the context-dependent variation in impacts is reflected in the high number of score ranges for afforestation.

ICS projects seem to positively influence the highest number of targets. Additionally, many of the positive interactions also received high scores. Interestingly, the estimated reduction in air pollution from deploying ICS is still insufficient to meet WHO recommendations. The assessment also identified many positive sustainable development impacts of off-grid PV projects, with the main drawback being the end-of-life treatment of the installations. Even though water filter projects are gaining increasing attention in the VCM, we could not identify a large number of impacts. The sustainable development impact of water filter projects particularly depends on the baseline scenario: boiling water or using untreated water result in very different sustainable development impacts (for example regarding health benefits).

A range of methodological insights can be drawn from this report. The choice of SDG targets and the exact project definition (including baseline scenario) significantly influence the identified sustainable development impacts. Careful consideration should be given to the selection of SDG targets in any future assessments of this kind. A thorough definition of the project type can help to clarify the impacts as broad project type definitions can lead to an increase in score ranges. A too narrow definition of a project type might restrict the applicability of the assessment to particular circumstances. Furthermore, the use of the SDG framework provides a useful and systematic assessment of sustainable development impacts. However, the identified impacts also depend on the interpretation of the phrasing of individual goals, targets and indicators.

The time horizon is also an important consideration for assessing sustainable development impacts. For all project types, the impact can significantly change depending on how the devices and installations are maintained throughout the lifetime of the project or how the afforested land is managed and preserved in the long run. Therefore, the results are constrained by the uncertainties about the long-term development of the impacts and only present the short-term impacts.

Finally, due to the fact that project types were generalized, and assumptions were made in the project definitions, the findings are associated with uncertainty. The results from this paper can be used as an indication of the number and the kind of SDG impacts which can be typically expected from the four project types. Buyers of carbon credits are encouraged to always seek out project-specific information to assess whether the generalized impacts presented here are applicable to the respective project in question.

Programs in the VCM differ in their requirements to assess and achieve sustainable development impacts. An evaluation of programs for this matter can be found in Wissner and Schneider (2022). Carbon credit buyers can achieve further assurance on sustainable development impacts by choosing a carbon crediting program that has robust environmental and social safeguards and provides for a sound assessment of sustainable development impacts.[8] Wissner and Schneider (2022) further include a list of project and programmatic aspects carbon credit buyers can pay attention to.

[8] The Carbon Credit Quality Initiative gives an overview of the quality of carbon credits from different programs: https://carboncreditquality.org/

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Annex I

Table 9: **List of targets selected for the assessment**

SDG	Target	Target explanation
1 - No poverty	1.1	By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than $1.25 a day.
1 - No poverty	1.2	By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions.
1 - No poverty	1.4	By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance.
2 - Zero hunger	2.1	By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round.
2 - Zero hunger	2.3	By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment.
2 - Zero hunger	2.4	By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.
3 - Good health and well-being	3.4	By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being.
3 - Good health and well-being	3.9	By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination.
4 - Quality education	4.2	By 2030, ensure that all girls and boys have access to quality early childhood development, care and pre-primary education so that they are ready for primary education.
4 - Quality education	4.3	By 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university.
5 - Gender equality	5.1	End all forms of discrimination against all women and girls everywhere.
6 - Clean water and sanitation	6.1	By 2030, achieve universal and equitable access to safe and affordable drinking water for all.
6 - Clean water and sanitation	6.3	By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe re-use globally.
6 - Clean water and sanitation	6.4	By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.
6 - Clean water and sanitation	6.6	By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.

7 - Affordable and clean energy	7.1	By 2030, ensure universal access to affordable, reliable and modern energy services.
7 - Affordable and clean energy	7.2	By 2030, increase substantially the share of renewable energy in the global energy mix.
7 - Affordable and clean energy	7.3	By 2030, double the global rate of improvement in energy efficiency.
8 - Decent work and economic growth	8.3	Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services.
8 - Decent work and economic growth	8.4	Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-year framework of programmes on sustainable consumption and production, with developed countries taking the lead.
8 - Decent work and economic growth	8.5	By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value.
9 - Industry, innovation and infrastructure	9.2	Promote inclusive and sustainable industrialization and, by 2030, significantly raise industry's share of employment and gross domestic product, in line with national circumstances, and double its share in least developed countries.
9 - Industry, innovation and infrastructure	9.4	By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased re-source-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities.
10 - Reduced inequalities	10.1	By 2030, progressively achieve and sustain income growth of the bottom 40 per cent of the population at a rate higher than the national average.
11 - Sustainable cities and communities	11.1	By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums.
11 - Sustainable cities and communities	11.4	Strengthen efforts to protect and safeguard the world's cultural and natural heritage.
11 - Sustainable cities and communities	11.6	By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management.
12 - Responsible consumption and production	12.2	By 2030, achieve the sustainable management and efficient use of natural resources.
12 - Responsible consumption and production	12.3	By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses.
12 - Responsible consumption and production	12.4	By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment.
12 - Responsible consumption and production	12.5	By 2030, substantially reduce waste generation through prevention, reduction, recycling and re-use.
15 - Life on land	15.1	By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements.

15 - Life on land	15.2	By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally.
15 - Life on land	15.3	By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world.
15 - Life on land	15.5	Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species.
15 - Life on land	15.9	By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts.

Source: United Nations (2015a)

This study was commissioned by

FOUNDATION Development and Climate Alliance

On behalf of the

Federal Ministry for Economic Cooperation and Development

Founded by:

KFW

Imprint

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Design cover photo
Studio Kunst GmbH

Photo credit
Thomas Okfen/GIZ, myclimate, iStock.com/Violeta Stoimenova,
ForestFinest Consulting, South Pole

Layout
AKRYL digital agency GmbH

May 2022