A review of community co-benefits of the clean development mechanism (CDM)

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Abstract
The Clean Development Mechanism (CDM) has been the major international offset mechanism within the broader world of carbon finance. It was designed with two goals in mind: to lead to significant emission reductions that will help reduce the cost of climate mitigation in countries with commitments as well as contribute to sustainable development in the host countries. However, there has been significant discussion about the degree to which these projects fulfilled their dual mission of emissions reductions and sustainable development, particularly with respect to fostering local community co-benefits as part of broader sustainable development outcomes. In this paper, we review literature on the co-benefits delivered by the CDM at the local or community level, based on a group of 84 peer-reviewed articles and other reports. While perspectives on co-benefits are diverse, most sources argue or acknowledge that even with more recent procedural improvements, the CDM has not consistently delivered significant co-benefits to local communities. It appears likely that the situation has improved somewhat in recent years as CDM procedures have been refined, and there may be more opportunities for enhancing procedures to favor such benefits. There is overall variability in delivering co-benefits depending on the technology type, design features and the country context.

1. Introduction

The world now has roughly a decade and a half of experience with the carbon offsetting programs established in Kyoto Protocol, most notably the Clean Development Mechanism (CDM). The experience of these programs can inform the next steps in the evolution of finance to support low-carbon sustainable development, including ongoing discussions about possible pathways for implementation of Article 6 of the Paris Agreement. Under the Paris Agreement, countries provided an option by which international emissions or offset trading could enable countries to advance and achieve more ambitious national emissions targets, pending ongoing discussions about the specific modalities and applications. Nevertheless, the mixed perceptions of the effectiveness of carbon offsetting mechanisms, including the CDM, have colored discussions of Article 6 and potential future mechanisms. One of the key questions surrounding the CDM’s legacy is how well it served local communities and national interests in sustainable development. This review synthesizes literature on those topics, focusing particularly on the delivery of local sustainable development co-benefits.

The CDM is probably the most salient international offset mechanism within the broader world of carbon finance and was hoped to lead to significant reductions of greenhouse gas emissions at the project level. Initiated under the Kyoto Protocol in 1997, the CDM was charged with carrying out the goal of assisting developed countries (‘Parties included in Annex I’) to achieve their Kyoto emissions goals using 4

4 Annex I parties include industrialized countries plus countries with economics in transition (UNFCCC 2019).
‘real, measurable and additional’ emission reductions carried out in other countries under the CDM regulatory architecture (UNFCCC, Article 12). Importantly, the CDM was explicitly designed with a co-equal, second goal, embedded in the Kyoto Protocol, of helping developing countries to achieve sustainable development7.

This second, sustainable development (SD) goal stemmed from an interest by Parties and by the international community in ensuring that the carbon finance approach in the CDM would not be just to identify low-cost reductions, but also to support broader development goals. The co-equal SD goal created challenges in interpreting and implementing the CDM, and as a result has been the subject of extensive inquiry. Operationalizing such an aspirational goal was further complicated by the absence of an internationally accepted definition of sustainable development in the context of specific projects and national priorities. The 2001 Marrakech Accords confirmed that the host country has sole authority to define whether a specific project contributes to sustainable development within that country: ‘The host country has the prerogative to decide whether a project assists in achieving sustainable development, and therefore should develop national criteria and requirements to ensure a coherent, justifiable and transparent assessment’ (UNFCCC, the Marrakech Accords). Because the interpretation of sustainable development thus varies from country to country, we would expect the impact of CDM projects on local community co-benefits could also differ.

There is now both extensive experience with CDM offset projects and a moderately large though diverse literature on the CDM experience. Assessing these existing projects can provide insights into the overall strengths and weaknesses of offset programs generally, as well as to the particular case of the CDM. As of this writing6, there are 7806 projects registered under the CDM and a total of 1.958 billion Certified Emission Reductions (CERs) have been issued (UNEP DTU Partnership). The extent to which these programs have supported sustainable development goals, and in particular benefits to local communities, has been evaluated by a number of research teams over the past decade. Drawing on these sources, this review presents a systematic literature review on the effectiveness of the CDM on providing development co-benefits for local communities, including an assessment of the factors that contribute to the outcomes, and potential lessons we can learn as future policy approaches are being considered.

Our focus in this review is on co-benefits at the local or community level, and does not extend to some other areas of active inquiry about CDM in the literature, notably the important question about the degree of emissions impact from offset projects (often referred to as ‘additionality’ in the literature)$. In addition, in undertaking this analysis, we aim to assess local co-benefits from CDM projects, and acknowledge that the literature we evaluate largely does not cover all potential negative outcomes from such projects, such as environmental or social impacts that may spill over into other sectors or resource availability in communities. Although our review reflects the literature’s predominant focus on this narrower assessment of specific co-benefits, we note that broader assessments may be an important part of a comprehensive evaluation of all potential outcomes from CDM-related projects.

Methodologically, the literature review presented here is based on a group of 84 peer-reviewed articles and reports from the grey literature. The review is organized as follows. Section 2 provides an overview of the systematic literature search strategy and discusses the challenges in defining local co-benefits. Section 3 presents the empirical evidence and observations generated by the literature. We present the policy findings and lessons learned from the literature, the implications for Article 6 of the Paris Agreement, and conclude in section 4.

2. Objective, scope and literature search strategy

2.1. Research objective

This paper reviews literature on the sustainable development co-benefits delivered by CDM projects, with a focus on the local level. Sustainable development has been broadly accepted as ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs’ (World Commission on Environment and Development 1987). However, turning this general definition into a specific application under CDM was a challenge. Unlike the additionality goal of the CDM, which is measured and monitored by the CDM Executive Board under the UNFCCC, there was no internationally accepted standard of sustainable development.

$Additionality is defined in the Marrakech Accords, which state that ‘a CDM project activity is additional if anthropogenic emissions of greenhouse gases by sources are reduced below those that would have occurred in the absence of the registered CDM project activity’ (UNFCCC decision 17/CP.7). Additionality has been the subject of extensive research on the topic of whether the CDM are able to meet environmental integrity and additionality requirements in practice in reducing GHG emissions’. (e.g. Carmichael et al 2016, Gillenwater 2011, Greiner and Michaelowa 2003, Paulsson 2009, Parshit and Michaelowa 2007, Da Silva Bastos Martins Barata et al 2016).

9 Although the definition of sustainable development from the Brundtland Commission is broadly accepted, there is still missing an operationalizable interpretation of sustainable development, which does not have a common standard.
The assessment of sustainable development benefits including local co-benefits was essentially delegated by the Kyoto Protocol to individual nations as a sovereign matter to its State parties, who essentially then developed guidelines that were applied to each individual proposed project in their respective countries. This approach, rooted in the Marrakesh Accords, allowed countries flexibility to design their own ‘menu’ of sustainable development options based on their capacities and priorities. Functionally, this was done via a specific institutional process. The international rules under the UNFCCC required each country to designate an agency within the government or other government entity to evaluate and approve CDM projects and oversee their implementation. This Designated National Authority (DNA), appointed by countries, was then also, by extension, charged with shaping the assessment of sustainable development for CDM projects. This assessment usually was rooted in some broader sense of priorities generated by the national government and then interpreted via a set of guidelines, indicators or preferred project types (Ellis et al. 2007).

Broadly speaking, the nature of the CDM thus creates three challenges for delivering sustainable development benefits, whether at local or national scales. The first challenge is rooted in the diverse interpretations of sustainable development under CDM. As a result of the nationally based structure of CDM, there were no standardized assessment criteria or monitoring systems. This has meant that many countries have not established strong systems for encouraging SD during the project development phase of CDM, or for monitoring sustainable development benefits during the implementation phase, potentially reducing the quality and quantity of benefits delivered (Dirix et al. 2016). Second, the CDM is a market mechanism that is designed to identify low-cost emission reductions. Facing possible trade-offs between easily quantitated emission reductions and harder-to-quantitate sustainable development benefits, project developers may favor those things more easily counted and more directly profitable. Third, the CDM does not establish any particular institutional or monetary incentives for projects that benefit the local communities, creating a potential gap that would have to be filled by voluntary action on the part of project developers or the DNA.

In this review, we focus on only sustainable development at the local level. This focus presents, in our view, two additional challenges to interpreting local community co-benefits in practice. First, the absence of an internationally accepted definition of sustainable development in the context of specific projects and national priorities moreover makes it challenging to define a clear and consistent set of criteria to evaluate local co-benefits. We addressed this issue by establishing a set of criteria as detailed in the next section. Second, for many countries, local co-benefits are only one dimension of their interpretations of sustainable development, which could include such other priorities as electricity generated for the national grid, enhancement of national income, purchasing of domestically produced goods, and others. Since most papers reviewed in this paper somehow invoke the term or concept ‘sustainable development,’ we addressed this issue by reviewing all such papers to see whether they specifically referenced benefits for local communities.

Methodologically, we implemented this review using a specific and emerging approach called a ‘systematic literature review.’ This process diverges from a more conventional literature review in using a transparent and structured approach to finding, selecting, and reviewing literature. More details about systematic literature reviews may be found in Petticrew and Roberts (2008). While traditional literature reviews have many merits, the systematic review methodology may reduce the possibility of bias in selecting and reviewing papers. For this reason, some organizations, including the World Bank, have created policies that encourage the use of systematic literature reviews.

The remainder of this section defines the specific research question to be answered by the review and articulates a transparent methodology to answer that question.

### 2.2. Defining local community co-benefits

A systematic literature review requires a formal exposition of research question(s) and hypotheses. The main research question for this paper was:

What does the existing literature say about the extent to which carbon finance projects under the CDM led to significant development co-benefits for local communities and what contributed to these outcomes?

A first step in answering this question is for us to define what is meant by local or community co-benefits in the context of this review. Although the idea of co-benefits attracted increasing attention among governments, NGOs, financial institutions, and academic research in recent years, there is no consensus on a concrete definition or agreed list of what counts as a co-benefit (Mayrhofer and Gupta 2016). The conventional concept of co-benefits as referred by the Intergovernmental Panel on Climate Change (IPCC) as ‘the positive effects that a policy or measure aimed at one objective might have on other objectives, irrespective of the net effect on overall social welfare’ (IPCC 2014). In this paper, we focus on a smaller subset of co-benefits, particularly on co-benefits to local communities as a result of the CDM mitigation actions (carbon projects) that are targeted at addressing global climate change.

Existing literature on how to evaluate co-benefits on carbon offsets projects can be categorized into two groups. The first area of literature focuses on looking at the benefits by using a ‘multiple-dimension,
multiple-indicator’ approach to evaluate co-benefits of carbon offset projects. The most commonly adopted methodology is to categorize benefits according to environmental, social, and economic benefits (Sutter 2003, Ellis et al 2007, Olsen 2007, Sutter and Parreño 2007, Nussbaumer 2009, Alexeew et al 2010a, Drupp, 2011, Crowe, 2013). The second area of literature contracts the focus of co-bene ts to specific areas in which concrete metrics of co-benefits can be feasibly measured or calculated. These include environmental indicators such as CO₂ or SO₂ emissions; or social/economic indicators such as income or employment (Sun et al 2010, Zhang and Wang 2011, Murata et al 2016, Mori-Clement 2019). It was our view that these broad areas were insufficient to fully describe local community co-benefits. In particular, the broad three-part categories lack a focus on specific routes to generating local benefits, and the metrics-focused approach may apply an overly narrow lens that might leave out meaningful qualitative contributions. Accordingly, we adopted a five-category typology in accordance with the World Bank CDCF’s definition (Boukerche et al 2013, CDCF 2017). These five categories are:

1. Enhanced local infrastructure (e.g. roads, health clinics, schools, water, parks, community centers, etc);
2. Access to cleaner and affordable energy for heating and/or cooking;
3. Improved income and employment;
4. Improved access to electricity and/or energy efficient lighting;
5. Improved natural resource and environmental services (e.g. reduced pollution, natural resource conservation, forest protection, biodiversity).

We then structured our literature review around these five categories, developing five sub-hypotheses based on these categories. These build out in more detail the ways in which CDM projects could have had positive effects on local co-benefits.

2.3. Review methodology
A systematic literature review uses a transparent search protocol to target the literature and conduct analysis. A detailed search protocol is provided in the supplemental materials (supplementary information E, available online at stacks.iop.org/ERL/15/053002/mmedia). In this paper, we covered both academic and grey literature.

2.3.1. Academic literature search
The search protocol was applied within academic reference databases and general search engines. The following databases were used to gather peer-reviewed literature: Academic Search Complete; Web of Science; Scopus; GreenFILE (EBSCO), Google Scholar and Google were used to capture additional possible papers. The search protocol sought to capture the maximum number of papers on the topic of ‘local community co-benefits’ as those terms intersected with CDM. This involved applying diverse search terms capturing the concept of co-benefits (e.g. co-benefits, community benefits, local community, local benefits, ancillary benefits, social benefits, economic benefits, environmental benefits, pro-poor, poverty alleviation, livelihoods, local employment) with ‘Clean Development Mechanism.’

Any search protocol has limitations, so we also sought to include references that were important in this literature but may not have been captured with our search protocol by examining references that were cited in the sample. However, including all references from all papers in the initial sample is neither practical or desirable. The ideal outcome is to find those referenced papers that are truly most important for the inquiry we are conducting. To do this in a systematic way, we developed and applied a backwards citation tracking process. We used a bibliographic computation software called VOSviewer10, which can calculate the total number of cited references from the general search sample. We then filtered the results based on a minimum number of citations within this sample for a given cited reference. We chose to apply a minimum of four citations within the sample11 as the threshold to generate a list of papers. We further narrowed that list to include papers published only between 2007 to present, primarily because we viewed these to be more likely to include a large enough history of CDM to be relevant. After comparing this list to the general search sample, we identified roughly 30 additional papers that our process indicated were important in this literature and were published after in roughly the past decade12. We added these to our original general search sample for evaluation in this review13.

2.3.2. Grey literature
The special characteristics of the carbon market, as a market mechanism spanning private and public sectors, multi-level international organizations, non-profit organizations, and others, imply that some perspectives from organizations and actors with direct

10 VOSviewer is a software tool developed by Nees Jan van Eck and Ludo Waltman at Leiden University’s Centre for Science and Technology Studies (CWTS). It is a tool used to conduct bibliographic analysis and scientific mapping.
11 Four was chosen as threshold because the marginal papers changing from four to three are 46; marginal papers from five to four are 16.
12 Example Output given above thresholds: Of 3564 total cited references within the sample yielded by our suggested protocol, 30 would be added as new entries.
13 The limitation of using VOSviewer is that it can only analyze academic papers that are in the Web of Science and Scopus database.
experience or other perspectives on the market can enhance insight into the questions in this review. Some sources that have not been published in academic, peer-reviewed literature can therefore also contribute to our understanding of carbon finance. We included select publications from this so-called ‘grey’ literature 14 in our study, subject to careful review.

We identified these potential grey literature publications via four methods. First, we obtained some reports (four total) from our method of backwards citation tracking described above. Second, searches were conducted for literature from a list of organizations selected for their engagement in the topic or potential relevance to this topic (see supplementary information A). Within this list, we applied the previous search terms for years 2007 present. Third, some selected relevant reports15 were identified ahead of time in consultation with colleagues in the field. Lastly, we also use a standard Google search16 to capture additional possible papers.

2.3.3. Inclusion and exclusion criteria
Systematic literature reviews require explicit utilization of criteria to filter or to include specific references. In this study, papers could be included only if they were either:

- Academic peer-reviewed and grey literature.
- Survey papers and studies of specific projects.

Papers were excluded if they were:

- Published before 2007 with fewer than 100 citations.
- From year 2007–2015, with fewer than 10 citations.
- For 2016 to present, we include all papers because they are the most up to date and may not have been cited as heavily yet.
- Pure policy discussion papers17 with citation number less than 50.

After applying these processes, we generated a sample of 84 references for this review. Table 1 presents the final breakdown of references in our review sample.

### Table 1. Total number of papers included in this literature review.

| Policy | Survey and project analysis | Clean development mechanism-afforestation/reforestation | Grey literature |
|--------|-----------------------------|--------------------------------------------------------|-----------------|
|        | 11                          | 32                                                     | 19              |
|        |                              | 19                                                     | 22              |

3. Observations and empirical evidence by co-benefit category

3.1. Literature review results
Relatively limited research has been conducted on the topic of carbon finance and community co-benefits. Of the papers in our sample, many of the papers are ex ante assessments based on categorizing expected benefits. Such papers would often utilize the relatively convenient samples of publicly available project design documents (PDDs) that are posted online. While having the advantage of being somewhat readily comparable, the unfortunate truth is that these documents reflect developers’ assessments of what the projects would deliver in terms of co-benefits—and are also documents that are used to secure approval for the projects. While providing some real insights into the characteristics of these project, they are far from an ideal evaluation tool. On the other hand, only a few papers in our sample are ex post assessments that provide evidence on impacts. One can presume that the greatly increased difficulty and cost of doing in-field assessments has hindered this category of assessment. Across both categories, most papers are heavily qualitative because of innate difficulties to measure and evaluate the co-benefits.

We evaluated the literature in our sample to assess the delivery of CDM co-benefits based on our predefined hypotheses. The hypotheses are illustrated in table 2. The upper part of the table explains how we extract papers to answer the first question based on the three categories. We assume that these three subgroups can show the difference of co-benefits generated from the CDM. Analysis of the reviewed literature showed that papers addressed four main issues relevant to the search protocol hypotheses, which we present in the lower part of the table.

3.2. Results on how co-benefits vary according to region, size, and technologies.
The ability of the CDM to generate local co-benefits varies among countries or geographic regions in part because of different policy approaches of governments.

3.2.1. Co-benefits vary among country/region
CDM projects’ record of delivering co-benefits has varied among countries, in part because countries have different interpretations of co-benefits to local communities. For example, Cole and Roberts
Table 2. Key issues addressed by reviewed literature.

| Research question | Subgroup                                                                 | Number of papers |
|-------------------|---------------------------------------------------------------------------|------------------|
| Question 1: what does the existing literature say about local co-benefits | Relationship of CDM across project technologies, size, and locations | 17               |
|                   | Impact of third party labeling for CDM projects                           | 9                |
|                   | Co-benefits specific to afforestation/reforestation projects               | 19               |
|                   | Trade-offs between emission reduction and sustainable development          | 10               |
|                   | Lack of agreement on co-benefits criteria and monitoring systems          | 5                |
| Question 2: What contributed to those outcomes?                            | Quality brands for CDM outperformed regular CDM projects in delivering co-benefits | 11               |
|                   | Strong local capacity and local stakeholder participation contributes to co-benefits | 19               |

compared Brazilian and Peruvian CDM projects to evaluate whether a country’s national priority and institutional capacity would have an influence on the delivery of co-benefits of CDM. They specifically asked whether project types or regulatory process in the domestic DNA approval is instrumental in creating co-benefits (Cole and Roberts 2011). After evaluating six hydro projects in Brazil and Peru, they found that the Peruvian government’s policy approach placed greater emphasis on local benefits, with a requirement for DNAs to visit project sites to assess local development needs. As a result, the Project Design Documents (PDDs) for these projects list detailed co-benefits that projects were expected to deliver. In contrast, the authors argue, the Brazilian government was more interested in attracting foreign investment to boost the economy through employment generation, and PDDs were consequently written in very broad and vague language with a focus on job creation. The authors cannot find specific local benefits in their Brazilian case studies. The study concludes that Peru’s approach18 encouraged delivery of co-benefits to the local communities on multiple dimensions that better matched local needs. Such needs included employment generation, purifying water, improving the local economy, and enhanced local infrastructure such as building roads, bridges, installing public phones, internet, building rooms for local schools and hospitals.

In another example, Spalding-Fecher et al. compared CDM project impacts across countries and found that CDM projects in India tend to bring more development benefits for local infrastructure than projects in China or Brazil (Spalding-Fecher et al 2012). The Chinese government’s sustainable development (SD) priority was focused on local environmental protection, as pollution is the most serious environmental problem for local governments in China. This study is not unique; for this review, most studies of Chinese CDM projects identified a common definition of co-benefits as reductions in SO₂, NOₓ, and particulate matter (PM) (Sun et al 2010, Zhang and Wang 2011, Murata et al 2016). From the study, we can also observe that countries interpret co-benefits differently based on their national priorities.

A Brazil-China-India comparison case study conducted by Castro and Michaelowa also confirmed that the CDM’s potential delivery of co-benefits varies among these three countries due to their different national strategies. In China, national priorities on energy efficiency improvement, development and utilization of renewable energy, and methane recovery encourage end-of-pipe CDM projects, while these projects offer limited co-benefits compared to other types of CDM projects. In India, national priorities were more focused on poverty alleviation and livelihood improvement, thus co-benefits are more aligned with these areas. In contrast, Brazil emphasized the co-benefits generated from the economic and income dimension. (Castro and Michaelowa 2008).

Regarding the regional distribution of development effects of the CDM, Least Developed Countries were noted by some studies as benefiting least from the CDM, since the share of CERs issued from registered projects in LDCs is only 1% of the total CDM portfolio (Spalding-Fecher et al 2012). Sub-Saharan Africa was frequently identified as the region benefiting least from the CDM even though these regions were also seen to have large potential for CDM to enhance local co-benefits. Developing CDM projects in this region faced challenges to development such as small-scale, high transaction costs and lack of local capacity. However, the development of new rules simplifying the CDM project cycle requirements for renewable energy

18 However, authors also mentioned the limitation of using ad hoc approach. Peruvians’ ad hoc approach lacks transparency and consistency based on its project-by-project method, and it creates room for potential abuse, while the Brazilian’s approach enables transparency and predictability at the expense of local co-benefits. So they proposed a middle path with an idea of a multi-stakeholder dialogue (Cole and Roberts 2011).
and Programs of Activity (PoA)\textsuperscript{19} seems to have improved the regional distribution of projects. Currently, the share of LDCs using PoAs is much higher than other country groups. One study found out that 30\% of PoA projects are in Africa, as compared to 2.9\% of traditional CDM projects, and in LDCs are 10\% and 1.1\%. (Spalding-Fecher \textit{et al} 2012) In allowing for much wider participation of smaller projects in these countries, these PoAs enabled additional contributions to local co-benefits. For example, the deployment of low-emission technology using PoAs benefits local communities where lack access to clean energy, water, improved access to electricity (Williams and Murthy 2013).

Even within countries, the development benefits of the CDM were found sometimes to be more likely to flow to regions with higher incomes due to elite capture. Dirix \textit{et al} conducted a literature review on the CDM’s contribution of poverty alleviation, and pointed out that more prosperous regions in China are more likely to attract CDM projects, in spite of the Chinese government’s efforts to direct investors toward the poorest provinces and regions (Dirix \textit{et al} 2016). Benecke studied the distribution of co-benefits in India on the state level. She includes four states, two with numerous CDM projects, and two with very few CDM projects. The two states with higher CDM projects have a lower proportion of the population below the poverty line, less violence, better policy and economic management, and a higher percentage of economic growth. (Benecke 2008). Her study suggests that as social and political conditions and historical experience can influence regional selection decisions for CDM projects, with consequent implications for co-benefits.

A World Bank report studying the Community Development Carbon Fund (CDCF) echoed these findings and expressed concerns on the imbalanced distribution of benefits among local communities. From their study of 22 CDCF projects, they found that even though CDCF projects were specifically oriented towards impoverished local communities, these projects ‘have not been fully successful in addressing the needs of the poorest of the poor,’ and found imbalanced distribution of co-benefits between communities and within the same community. Two case studies in Nepal and Bangladesh reveal that the poorest families were unable to benefit from these projects due to high upfront investment costs, not to mention follow-up maintenance and operation costs (Boukerche \textit{et al} 2013). Some studies show that even small RE projects, which are supposed to benefit local communities, make richer farmers and the urban population the ultimate beneficiaries if there are no mechanisms to ensure that benefits flow of the poorest (Glomsrød \textit{et al} 2011, Michaelowa and Michaelowa 2011).

3.2.2. Co-benefit variation across project technologies

The reviewed literature found substantial variation in local co-benefits across different project technologies. A detailed breakdown of the literature by specific technologies is provided in table B1 in supplementary information B.

Trifluoromethane (HFC-23) projects were seen to deliver few tangible local co-benefits (Ellis \textit{et al} 2007, Schneider 2007, Sutter and Parreño 2007, Olsen and Fenhammer 2008, Alexeev \textit{et al} 2010a, Subbarao and Lloyd 2011, Watts \textit{et al} 2015). While they create large quantities of low-cost emissions reductions (though the true contribution to overall reductions can sometimes be murky), these projects have a low impact on generating local employment\textsuperscript{20} and no effect on improving local air quality\textsuperscript{21}. Most of the profits from the destruction of HFC-23 in HCFC-22 facilities went to project developers and government\textsuperscript{22}. Although in some cases governments argue that they can use this tax revenue to deliver local co-benefits indirectly, this is out of the scope for our review, since it is unclear whether this pathway will be utilized effectively.

Landfill gas reduction projects also face a similar situation to HFC-23 projects in their capacity to deliver high emission reductions but with low co-benefits, and in some cases, also appear to have engendered opposition from local communities. Such projects are associated with few direct jobs because the technology they employ does not require significant numbers of workers. Regarding environmental co-benefits, landfill gas projects may have contributed to improved sanitation and water quality, with potential health benefits. However, there have also been community concerns about negative impacts on local health from methane gas or other non-methane landfill, gases, for new landfills or composting sites around local community or an extension of the life of an existing site. Two out of five papers reported concerns of local communities regarding negative impacts\textsuperscript{23} (Ellis \textit{et al} 2007, Boyd 2009).

Hydropower assessments usually distinguish between large hydro and small hydro projects. Consistent with a broader literature on hydropower impacts, large hydropower projects were broadly

\textsuperscript{19} ‘Under a programme of activities (PoA) it is possible to register the coordinated implementation of a policy, measure or goal that leads to emission reduction. Once a PoA is registered, an unlimited number of component project activities (CPAs) can be added without undergoing the complete CDM project cycle’.

\textsuperscript{20} The projects are end-of-the-pipe solutions and do not have a substantial employment effect.

\textsuperscript{21} Because industrial gases like HFC-23 are not local air pollutants, the destruction of them does not provide local environmental benefits for local communities.

\textsuperscript{22} For example, Chinese government tax 65\% of the CERs of HFC-23 projects. By 2012, the expected tax revenue from this project type can be 1.5 billion EUR (Schneider, 2007).

\textsuperscript{23} The Bisasar landfill CDM project in South Africa was criticized by local communities, who claim that the CDM projects is contributing to postponing the closure of the waste disposal site, which had a negative impact on people’s health (Boyd \textit{et al} 2009).
criticized in the literature as bringing negative impacts to local communities (Haya 2007, Haya and Parekh 2011, Rousseau 2017), though it should be noted that such negative impacts were omitted by project developers in the PDDs. Also, compared to small hydro, large hydropower plants appear to generate fewer co-benefits to local communities (Sutter and Parreno 2007). A case study in Yunnan Province in China revealed that the CDM hydropower project negatively changed local people’s lives as local smallholders lost their most important asset, their land, to the dam reservoir. As a result, the benefits of the hydro project are captured by the wealthy eastern provinces, where they have a high demand for electricity, and local communities experienced negative impacts from the CDM.

Renewable energy projects, such as small hydropower projects, wind and EE are generally recognized as having the potential to generate more co-benefits to local communities. Like other types of projects, these projects can provide broad SD benefits for the country, such as increasing energy security improving air quality, and achieving technology transfer. In addition, they are seen as having a high possibility to deliver local co-benefits, such as employment generation, income generation, access to energy, improved local air quality compared to other technologies (Olsen and Fenhann 2008). Alexeew conducted a study of 40 projects with a diversity of project types in India. By looking at their PDDs, he concluded that among the project types, biomass, hydro and wind projects contribute higher SD benefits than HFC-23 (Alexeew et al 2010a). Additionally, off grid renewable energy projects in rural areas offer local communities a sustainable and viable alternative to fossil fuels, in part because of the cost and challenge to distribute centrally generated, fossil-fueled electricity to remote or rural areas (Subbarao and Lloyd 2011).

Reviewed studies indicated biomass projects can create some benefits to local air quality, while also supporting performance on employment generation. Sutter’s study shows that only biomass power project received an A rating24.

3.2.3. Co-benefit variations by project size
The reviewed studies conclude that small-scale projects tend to deliver a slightly wider range of local co-benefits per project than large-scale projects27 (Sutter and Parreno 2007, Olsen and Fenhann 2008, Corbera et al 2009, Spalding-Fecher et al 2012). Olsen and Fenhann, for example, found out that small-scale projects deliver a slightly wide range of SD benefits than large-scale projects (3.2 benefits28 per project for small vs 2.9 benefit per project for large) (Olsen and Fenhann 2008). On the other hand, large scale projects showed outperformance on improving air quality, water, and health.

Sutter and Parreno rated SD attributes across projects and found that the average SD rating27 was higher for small-scale projects (Sutter and Parreno 2007). Similarly, Spalding-Fecher’s study of 202 projects, where 79 were small-scale and 123 were large-scale projects, indicated that SD benefits are mentioned more often for small-scale projects compared to large-scale projects; moreover, for 5% of large-scale projects, no other SD benefits other than technology transfer was mentioned. Dechezleprêtre’s study agreed with the technology transfer conclusion but reached a differing view on the relationship to size, concluding that the larger the project, the bigger the benefits from the more likely of technology transfer due to the economies of scale in technology transfer (Dechezleprêtre et al 2008).

A major limitation of these conclusions is that most of the studies, as noted earlier, were conducted based on a desk study of PDDs, which describe only the expected benefits from the project, and moreover describe them from the developer’s perspective. This significantly limits their ability to assess real impacts on the ground. Subbarao and Lloyd conducted one of the few studies using a mixed method of a desk-study and case study with five projects. Their results showed that CDM projects failed to deliver significant or substantial SD benefits to localities. However, three out of the five cases revealed factors, including active local stakeholders and communities’ involvement, that can contribute to the success of the CDM projects and their ability to deliver local co-benefits (Subbarao and Lloyd 2011).

3.2.4. CDM Afforestation/Reforestation
We consider CDM Afforestation/Reforestation projects (CDM-AR) projects separately because of their unique characteristics, the small number of registered projects and the minimal coverage in the literature. Currently, there are only 66 registered CDM-AR projects27. Compared to the extensive literature of standard CDM projects, the CDM-AR literature is likely smaller because of the more limited number of CDM-AR projects and the relative newness of this category. However, similar to the other CDM literature, among the CDM-AR literature, most of the literature focuses on the potential of such projects, rather than outcomes: only four of 19 reviewed studies

24 This study shows that only biomass power project can generate more than 300 persons month per CER, while the average employment of industrial gases is 2.3 persons month per CER.
25 Most of the studies have multiple co-benefits indicators. Each indicator represents one benefits. So, they will look at how many indicators one project can get.
26 This study defines 13 SD criteria in the taxonomy, thus there are 13 different types of benefits.
27 There are nine small-scale projects and seven large-scale projects. Each project was assigned a SD rating by the authors from A to E.
28 Data from UNEP DTU Partnership by 1 November 2017. 10 projects are afforestation, and 55 projects are reforestation.
of CDM-AR actually assess results from the registered CDM-AR projects (Jindal et al. 2008, Thomas et al. 2010, Brown et al. 2011). Due to the longer duration of the CDM-AR projects, it remains to be seen whether CDM-AR contribute to local co-benefits. Moreover, as one author pointed out, the delay in return also limits participants’ willingness to engage, noting it was the primary obstacle to consideration of engaging in CDM-AR projects from a landholders’ perspective (Thomas et al. 2010).

Two of the three papers using a field study show positive co-benefits mainly focused on improved income and employment and improved natural resources in environmental services in the local area. One paper highlights limitations in CDM-AR projects based on a review of four projects in India (Aggarwal 2014), arguing that the high opportunity costs attached to the land due to fast economic growth cannot be covered by revenues and other benefits from the CDM. Additionally, two grey literature reports focus on the World Bank BioCarbon Fund (BioCF) initiative with a total of 21 CDM-AR projects (Salinas and Baroudy 2011, Hagbrink 2012). These 21 projects are found to deliver co-benefits to the local communities, such improved local income and employment, improved local environmental, and improved local capacity.

Thomas et al. studied the only four CDM-AR projects existing at the time of their paper. They list factors leading to ‘success’, such as access to start-up funding, engagement of large NGOs with their capacity for technical support, involvement of local communities, land ownership of local communities, and others (Thomas et al. 2010). Jindal et al.’s study covers 23 forestry-based carbon sequestration projects in Africa. Among these 23 projects, two are CDM-AR projects. While they argued that a full assessment of co-benefits was premature at that time, based on their field research in two countries, they raised concerns that the lack of institutional capacity and political stability in Africa might prevent projects delivering benefits to local communities (Jindal et al. 2008). Brown’s case study from Humbo, Ethiopia shows positive impacts for livelihoods and environmental benefits from the CDM-AR projects through the establishment of user rights and empowerment through training local farmers. Furthermore, the project trained local farmers to use farmer managed natural regeneration (FMNR) techniques. Thus, not only there are direct revenues from the sales of CERs, but farmers were also able to generate additional income through new skills.

The rest of the literature focuses on experience of CDM-AR projects in local communities. Some papers focus on the perspectives of stakeholders, and conclude that weak institutions, lack of capacity, and land ownership issues are shared concerns across the papers (Boyd et al. 2007b, Corbera and Brown 2008, Palm et al. 2009, Bozmoski and Hultman 2010, Nijnik and Halder 2013a). Most authors addressing feasibility of the CDM-AR projects point out that there is a high expectation from the local communities regarding the CDM-AR projects. Another group studies specific barriers and obstacles (such as economic, financial and intuitional barriers) that might prevent potential CDM-AR projects from delivering benefits to local communities (Minang et al. 2007, Boyd et al. 2007a, Coomes et al. 2008, Zomer et al. 2008, Paquette et al. 2009, Lasco et al. 2010, Glomsrød et al. 2011). Many authors also proposed considering forest conservation activities (such as REDD), which could create more benefits on shorter time horizons for the local community (Coomes et al. 2008, Singh 2008, Lasco et al. 2010, Thomas et al. 2010, Nijnik and Halder 2013b).

In summary, the limited CDM-AR experience precludes broad understanding of real co-benefit impacts, but initial experience indicates the potential for such benefits under good governance by local communities. The small group of papers that were able to assess registered CDM-AR projects found significant co-benefits to the local communities. On the other hand, although there were some positive experiences documented in these papers, because of limited literature and numbers of CDM-AR projects, there was no broad consensus or demonstration of how CDM-AR broadly contributes to local co-benefits. One of the primary driving factors in this limitation is the duration of time it takes for forests to mature and thereby to generate revenues.

3.3. Factors of outcomes
3.3.1. Trade-offs between emission reduction and sustainable development

Many studies agree that the CDM, as a market-based mechanism, has generally succeeded in directing investments to projects with low-cost emissions reductions. Under a system in which revenues from emissions reductions are a dominant driver of project development (which is largely how the CDM functioned in early phases), large projects with the potential of generating large volumes of CERs at low cost (e.g. HFC-23, methane reduction) would be favored, even though these kinds of projects may generate few or no co-benefits for the local community. However, this is also a fundamental tension of the CDM: the original idea of the CDM is not only to look for the cheapest way to reduce GHG emissions, but also to promote sustainable development (Pearson 2007). Moreover, the CDM only directly measures and rewards behaviors that reduce emissions; no monetary value is assigned to co-benefits. Many researchers studying whether the CDM can deliver its dual goals found that there was therefore often—though notably, not in every case—a trade-off between emission reductions and sustainable development. (Ellis et al. 2007, Schneider 2007, Sutter and Parreño 2007, Alexeew et al. 2010a, Freeman and
Zerriffi, Torvanger et al, Watts et al). In other words, many projects that offered low-cost, high volume emissions were not necessarily those that maximize development benefits.

Schneider conducted a study of 93 projects and found a clear trade-off between additionality and benefits for sustainable development. This paper asserted that projects focusing on HFC-23, N₂O and landfill gases, and methane are most likely to be additional, but that these kinds of projects were seen to create few co-benefits for local communities. On the other hand, they found that some projects such as RE (except biomass), and EE generated high co-benefits to local communities but had more marginal additionality characteristics (Schneider 2007).

Sutter and Parreño surveyed 16 projects and found that none would have a high likelihood of delivering both additionality and local SD benefits (Sutter and Parreño 2007). Their evidence shows projects clearly prioritized cost-efficient emission reduction, while sustainable development was largely neglected (Sutter and Parreño 2007). The bigger the project size, the higher likelihood of real emission reductions, while the lower likelihood of contribution to the co-benefits. In contrast, smaller hydro and biomass projects exhibited higher contributions to local sustainability with lower likelihood of emission reductions. Overall, they found that 95.7% of CERs contributed minimally to local SD with a high likelihood of emissions reductions. Alexeev conducted a study of 40 projects with a diversity of project types in India and find a similar conclusion, with no projects yielding high SD benefits and a high probability of being additional (Alexeev et al 2010a). It should be noted that these studies focused particularly on the early, more lightly regulated phases of CDM, a topic which we will return to later.

3.3.2. Lack of agreement on co-benefits criteria and monitoring systems

As noted earlier, it is the responsibility of host countries to define the term ‘sustainable development’ as well as to establish and monitor the co-benefits criteria. Under international guidelines, then, countries are free to design their own sustainable development ‘menu’ based on their capacities and priorities. This creates uncertainty and heterogeneity in how SD and co-benefits are interpreted, as well as disparities in funding of supporting these SD projects. Additionally, host countries face challenges of establishing and monitoring CDM projects, especially for small-scale projects. Because small-sized CDM projects are large in a number but small in resulting CER volumes, it is difficult to set individualized criteria and monitor every project. Studies show that in countries where there were not well-established SD criteria with a robust monitoring system, even small-scale RE projects that might have been expected to deliver local co-benefits nevertheless failed to deliver them (Macdonald 2010, Subbarao and Lloyd 2011).

Thus, some authors proposed to reform the CDM to include specific SD criteria and to ensure that specific kinds of co-benefits be delivered to local communities (Corbera et al 2009, Macdonald 2010, Dirix et al 2016). However, others noted the challenge of accommodating national sovereignty considerations if an international standard is created without national inputs. As a result, minimal international standards for SD benefits, while incorporating a host country’s rights to regulate a given CDM project’s sustainable development, should be considered (Boyd et al 2009, Spalding-Fecher et al 2012).

3.3.3. Co-benefits from CDM projects associated with World Bank or external quality labeling

The broader literature suggests that indicators of quality, such as labeling or institutional endorsements, might correlate with higher delivery of intangibles or non-monetary returns on investments, such as community co-benefits. We reviewed assessments of three types of ‘labeling’ for CDM projects, including initiatives supported by different funding sources. Such projects included the CDM ‘Gold Standard’ label, as well as others generated under the World Bank’s Community Development Carbon Fund and the Climate, Community, and Biodiversity Standard. Unlike the regular CDM, which makes no claim to the specific co-benefits that the CDM generates, these labels or other indicators can potentially signal to CER purchasers that a labeled project has higher co-benefits and this might then generate higher CER prices. This could incentivize project developers to promote local co-benefits in a different way than just for standard CDM projects. We have attached the list of papers we reviewed in table C1 in the Supplementary Information.

The Gold Standard (GS), initiated by the World Wide Fund for Nature (WWF) in 2003, is a certification standard for carbon offset projects. A CDM project can use GS as an add-on methodology to make it a GS CDM project. GS is a voluntary scheme based on the CDM structure, with three additional ‘screens’ to filter projects. The first screen is ‘project type screen’, which limits projects only to renewable energy and end-use energy efficiency projects. The ‘additionality and baselines screen’ seeks to ensure projects are additional. The ‘sustainable development standards screen’ seeks to ensure projects that deliver local, social, environmental and economic benefits (Gold
Standard (2002). Once projects passed these screens, they are labelled as GS projects. Nussbaumer noted that this methodology was able to ‘secure’ local, social, environmental and economic benefits’ (Nussbaumer 2009). The Climate, Community and Biodiversity (CCB) Standard is another standard applied to CDM, this one created to foster the development and marketing of projects that deliver credible and significant climate, community and biodiversity benefits in an integrated, sustainable manner (CCB Standard version 3). It focuses on local stakeholder engagement by requiring consultations with stakeholders (Wood, International Institute for Environment and Development, Sustainable Markets Group 2011).

While GS and CCB are the only programs specific to labeling CDM projects, several other project initiatives utilized the CDM architecture and generated portfolios of projects according to specific quality and outcome criteria. Most notably, there are three initiatives of the World Bank Group that aim to use the CDM to promote targeted areas and project types. The Community Development Carbon Fund (CDCF) represents a different approach using a specific funding mechanism to support projects to benefit local communities. Created in 2002, the CDCF’s original goal is to support small-scale projects within underprivileged communities to promote the local co-benefits by offering the project developers a price premium for CERs. By May 2017, by its own assessment, 25 out of 36 registered CDCF CDM projects successfully delivered tangible co-benefits ‘aligned with the SDGs for approximately 17.5 million people’ (CDCF 2017). Created in 2004, The BioCarbon Fund (BioCF) had 18 CDM-AR projects by the end of 2012 and successfully reduced deforestation in over 350,000 hectares of land over a decade ( Hagbrink 2012 ). Another study with 21 CDM-AR projects shows that the co-benefits to the local communities in environmental, social and economic dimension in a significant manner (Salinas and Baroudy 2011 ). In December 2011, the World Bank launched the Carbon Initiative for Development (Gi-Dev) to ‘build capacity and develop tools and methodologies to help the world’s poorest countries access carbon finance, mainly in the area of energy access’ (The Carbon Initiative for Development (Gi-Dev) 2015 ). By June 2016, there were 13 CDM PoAs which were selected by the Gi-Dev to promote the energy access such as rural electrification, energy efficient cookstoves, and low-carbon water filtration ( Michaelowa et al 2016 ). With this specific targeted area of energy access, the Gi-Dev has potential to deliver tangible co-benefits to these underprivileged communities.

Following Sutter’s MATA-CDM method 34 , Nussbaumer conducted an early study comparing the potential local sustainable development benefits of labeled CERs (GS and CDCF) to regular CDM projects. A total of 39 CDM activities were evaluated, which includes all GS and CDCF CDM projects at the time of the study. The study found that the sustainable development profile of labeling CDM projects tends to be comparable or slightly higher than similar ordinary projects. ‘Labelled projects do not, however, drastically outperform non-labeled ones’ (Nussbaumer 2009 ). However, Drupp later noted that Nussbaumer’s study was limited by the small number of GS projects available at that point in time. He conducted a similar study by using MATA-CDM method, with more GS projects in the sample and compared 18 GS projects with 30 regular CDM projects. He found that: (1) GS can be associated with distinctly higher potential co-benefits to local communities than these 30 unlabeled CDM projects; (2) the impact from GS is even more pronounced if compared with unlabeled CDM projects whose project technologies are unqualified for the GS requirement (3) GS’s impact on co-benefits is ‘inclusive’ 35 in a within-project-type comparison (Drupp 2011 ). The author did not find ‘detectable potential co-benefits surplus generated by the sustainable development standards screen.’ However, the analysis did suggest that the ‘project type screen’ works, which means renewable energy projects outperform non-RE projects on delivering co-benefits. Crowe expands the sample further to consider a total of 114 projects, which constitutes 17 GS, 4 CCBs and 89 regular CDM projects. He concludes that regular CDM projects are only ‘marginally’ successful at delivering pro-poor benefits, while GS projects are only slightly better at delivering co-benefits compared to regular CDM, but that all four CCB projects performed well in delivering pro-poor benefits. Crowe’s approach also included a market survey to analyze the carbon market participants would be willing to pay higher prices for projects with stronger local development benefits 36 (Crowe 2013 ). Additionally, another study of willingness to pay for the GS projects finds that 56% of the buyers are willing to pay a price premium (Parnphumesup and Kerr 2015 ).

3.3.4. Strong local capacity and local stakeholder participation contributes to co-benefits

Cole and Roberts assessed the determinants of the SD benefits from a sample of CDM projects across technologies and host country geographies to see if other factors besides project technologies or capacity of DNA can influence the deliverability of local co-benefits. They reviewed six small-scale CDM projects in Brazil and Peru, and found that addressing local

34 Multi-Attributive Assessment of CDM (MATA-CDM) methodology, which was introduced by Sutter (2003) to evaluate the contribution of CDM projects to sustainable development in host countries (Sutter and Parreño 2007).

35 Inclusive, means that author cannot conclude from their analysis that GS projects can be associated with higher co-benefits than similar unlabeled CDM projects.

36 Of course, as the author also identifies, there might be a response bias in the survey because people tend to gravitate toward good behavior by picking the better answers (Crowe 2013 ).
community needs and engaging local stakeholders was key to delivering benefits to local communities in Peruvian cases (Cole and Roberts 2011). Other researchers confirmed the importance of engagement of local communities and local stakeholders from their field studies (Uddin et al 2007, Brown et al 2011, Subbarao and Lloyd 2011, Crowe 2013).

The CDM validation process requires an appropriate stakeholder consultation for every project. However, research found the quality of stakeholder consultation is uneven and frequently questionable. Project developers can strategically invite selected stakeholders to be in the consultation. Thus, those individuals or local communities that are likely to be affected by the project might be left out from the process. Schneider found out that in 25% of their analyzed projects, only selected stakeholders’ comments were provided in the documents. Additionally, another 33% of the projects had no clear information of stakeholders’ comments, and for another 39% of projects, announcements were simply distributed through media of unknown efficacy, with the most common way of using loudspeakers (Schneider 2009).

The experience of CCB echoes these themes on the importance of building local capacity, particularly on the need for greater engagement of local communities. In this literature sample, all cases where CDM projects successfully delivered local co-benefits involved robust engagement of local communities and local stakeholders (Crowe 2013, Wood, International Institute for Environment and Development, Sustainable Markets Group (2011)). Where CDM projects failed to achieve local co-benefits, one of the main reasons is that there is no local capacity to be aware of, understand, and fully utilize the CDM (Boyd et al 2007b, 2009, Ellis et al 2007, Sirohi 2007, Corbera et al 2009, Gillenwater and Seres 2011, Schomer and van Asselt 2012, Dirix et al 2016). Two studies employed econometric models and demonstrated local community engagement is essential for realizing development outcomes (Glomsrod et al 2011, Kim et al 2013). A key point of consensus in this literature, then, is that improving local capacity is a key to fully achieving local co-benefits. More importantly, in any new carbon market architecture, these studies suggest that enhanced local capacity should play a critical role in order to enable developing countries, especially LDCs, to achieve more benefits toward both global climate and development outcomes.

4. Summary and discussion

4.1. Synthesis: overall assessment of local co-benefits
Evaluating experience with CDM is challenging: despite the large number of actual projects, the documentation for such projects has been minimal and inconsistent over time and across countries; the policies and procedures have evolved significantly over time; and relatively little literature exists that seeks systematically to assess outcomes and the efficacy of this important policy intervention. This is in many ways understandable: the ‘learning by doing’ process for CDM led to heterogeneity in project concept and execution in its early years and even in the more mature phase, few resources were devoted to overall assessment. There have nevertheless been concrete changes in CDM processes since its initiation, and studies argue that over the years it has improved.

While perspectives on co-benefits from CDM are diverse, most sources argue or acknowledge that even with more recent procedural improvements in the operation of the CDM designed to reduce less desirable project types, the CDM has not consistently delivered significant co-benefits to local communities. The delivery of co-benefits from CDM has varied across technology type, design features and the country context. Noting that broad generalizations are unlikely to be true for all project cases in a specific category, there were some trends with respect to technologies. Different technologies may be able to deliver different scope and dimensions of co-benefits to local communities based on the very nature of the technologies themselves. Second, there may exist some patterns observable by country. Again, while broad generalizations must be viewed cautiously because of the evolving and project-specific nature of CDM approval and implementation, several patterns were evident.

This literature review examined five specific co-benefit goals: enhanced local infrastructure; access to cleaner and affordable energy for heating and/or cooking; improved income and employment; improved access to electricity and/or energy efficient lighting; Improved natural resource and environmental services. Table 3 summarizes a topical breakdown of papers assessed for each local co-benefit area (including regional focus, research methods, project types, project sizes and externalities). In addition, table D1 in the Supplementary Information presents a summary of CDM benefits literature in these five categories. The review finds the following general patterns.

Of the five co-benefit categories investigated, local employment and economic income impacts are the most frequently assessed in the literature. For example, all three studies of CDM-AR projects mention improved income and local employment, and many papers assessing regular CDM projects’ PDDs found that increased income and local employment are the most frequently mentioned anticipated benefits. Because almost all projects have at least a short-term need for labor, most can generate some employment. Even in the comparison case study between Brazilian and Peruvian projects, projects in Brazil failed to deliver almost all co-benefits except economic income. However, although this impact is discussed consistently across projects, the real outcomes and degree of success in terms of both quality and quantity of
employment and the long-term economic impact remain poorly studied and understood.

Improved natural resources in environmental services are the second most frequently assessed in the literature. Specifically, papers assessing standard (non-labeled) CDM projects’ PDDs found out improving local air quality and environment are the second most mentioned co-benefits in the PDDs. On the other hand, several papers focusing on China limited their interpretation of co-benefits to just air pollution, focusing on mitigation of SO\textsubscript{2}, PM, and NO\textsubscript{x} with no consensus in those papers on the outcomes. All CDM-AR projects discussed the potential to improve environmental services, with studies assessing registered CDM-AR projects finding improvement in natural resource benefits.

Access to cleaner and affordable energy for heating and/or cooking and improved access to electricity and EE lighting appeared to provide moderate levels of co-benefits for regular CDM projects. If we include third-party or external quality labeling CDM projects, with their targeted nature of project technology, co-benefits from these CDM projects are significant. There are, however, only a limited number of third-party or external quality labeling CDM projects assessed in this category.

Enhanced local infrastructure is the co-benefit that has the least coverage in the literature, although it is acknowledged to facilitate other co-benefits, particularly in poorer areas. None of three papers studying registered CDM-AR, for example, mentioned a direct improvement in local infrastructure. Four papers analyzing the co-benefits across these five indicators, all found that enhancing local infrastructure has the lowest performance compared to the rest of four indicators. The lack of literature in this area precludes a broader statement of consensus.

Negative impacts of projects on local communities are a complementary but indispensable dimension of discussing CDM projects’ co-benefits. Our review in this paper focuses on the co-benefits of projects, which is an inherently positive framing, but it is also necessary to acknowledge that projects, whether through poor design or poor implementation, may generate negative local consequences. This aspect was mentioned by 14 of the papers in our review as described in table 3. These papers can be broadly categorized into three groups. The first group expressed several concerns of CDM-A/R projects in local communities, which might lead to local ecosystem damage, such as by converting of grasslands into plantations, by focusing on single plantations, by fast growing exotics (Aggarwal 2014, Jindal et al 2008, Klooster and Masera 2000, Nijmik and Halder 2013b, Olsen and Soezer 2016). The second group notes the negative and sometimes severe impacts on river ecosystems and communities from large hydro projects (as discussed earlier). The last group identifies negative impact on human health or well-being directly through project activities such as landfill gas projects raised concerns about the loss of livelihood for garbage pickers (Boyd et al 2009, Haya and Parekh 2011, Michaelowa and Michaelowa 2007, Spalding-Fecher et al 2012). In addition to those papers sampled by our method, some other, recent literature explores trade-offs between increased energy access and broad SDG goals (Deng et al 2017, Fusio Nerini et al 2018, McCollum et al 2018). This growing body of research reveals the complex dynamics among different SDG goals from projects which aim to bring sustainable development to local communities. While a broader review of negative impacts would be valuable—for example, on how to design projects and implement mechanisms to minimize negative impacts—it is beyond the scope of this paper.

4.2. The value of diverse methodologies for assessing community co-benefits
Our review covers papers with diverse methodological approaches to understanding co-benefits. For the purposes of assessing local outcomes, valuable insights into the co-benefits of CDM projects were provided by field case studies, interviews, and surveys. 14 papers in our review adopted a qualitative case study method, with an additional 8 papers used survey and interview method. As described in section 2.3, another approach of many published studies was to review PDDs and

Table 3. Typology of co-benefits papers\textsuperscript{*}.

| Co-benefit type | Continent | Method | Project type | Project size | Externality |
|-----------------|-----------|--------|--------------|--------------|-------------|
| All five goals (35)\textsuperscript{a} | Global (40) | Economic (5) | All (39) | Both (53) | Positive (72) |
| Goal 1 (6) | Africa (8) | Science and engineering (16) | A/R (19) | Large (3) | Negative (14) |
| Goal 3 (25) | Asia (17) | Social science (33) | Biomass (1) | Small (16) | |
| Goal 4 (5) | North America (4) | Other (18) | Cookstove (2) | | |
| Goal 5 (18) | South America (5) | | EE (3) | | |

\textsuperscript{*} Developed through the hand-coding of papers from the systematic review according to co-benefit type, continent, research method, project type, project size and externalities of project impacts.

\textsuperscript{a} Numbers in parentheses are counts of papers.
from those, assess sustainable development. While these studies can provide helpful insight into the motivations for projects, this methodology is limited in its ability to assess real impacts of these projects on the ground, since the PDDs are generally prospective and do not measure actual co-benefits. Of the papers in our sample, 18 papers used qualitative textual analysis by reviewing the PDDs. However, compared to \textit{ex ante} assessments based on categorizing expected benefits, \textit{ex post} assessments that provide evidence on impacts do have increased difficulty and cost, which present an obstacle to this approach.

A second aspect of differentiation was the scale of assessment, ranging from global aggregation or comparative analysis to detailed assessment within a specific country. Table 3 indicates that there are about 40 papers with a global perspective on co-benefits of the CDM projects, while the rest of papers focus on Africa (8), Asia (17), North America (4), and South America (5) respectively. For the community co-benefits focus of this review, those papers focusing on specific countries or localities generally provided results that were more salient.

Finally, the literature demonstrates a trade-off between reviewing general portfolios of project technologies vs. specific technologies. Of the papers we reviewed, the majority of the papers assess across multiple project technologies, while only a few papers focus on studying one or two specific project technologies, such as solar and biomass. While a systematic approach to assessing outcomes across technologies would be valuable, the level of detail in the more focused studies tended to be higher and, at least at this stage, more helpful for assessing community co-benefits. Future work in more detailed systematic assessments could therefore be valuable.

4.3. The viability of linking sustainable development and mitigation finance

As a policy tool with dual goals—of low-cost emissions reductions and sustainable development—the CDM has always had a challenging mandate. One fundamental challenge of the CDM’s ability to deliver local co-benefits is the market nature of the mechanism, in that there exists a trade-off between monetized carbon emission activities and non-monetized sustainable development. The ambiguity in both the characterization of local co-benefits as well as the relative importance of local benefits in assessing the broader goals of sustainable development has led to an inconsistent and often weak or inconsistent application of this sustainable development goal to approving and assessing projects.

However, there do exist success stories. All successful projects reveal the importance of engagement from local stakeholders and communities. Smits and Middleton for example identify two case studies with different sustainability outcomes due to the lack of an international standard (Smits and Middleton 2014). Many papers therefore have proposed establishing an international standard to assess, measure and monitor the deliverability of local co-benefits in the long term (Corbera et al 2009, Dirix et al 2016, Ellis et al 2007, Macdonald 2010, Nussbaumer 2009, Sirohi 2007, Smits and Middleton 2014, Sutter and Parreño 2007). However, some scholars raised the issue of how to accommodate national sovereignty considerations if an international standard is created without national inputs. It was suggested that an international standard or ‘checklist of SD benefits’ would allow each nation to make their own interpretations (Boyd et al 2007b, Spalding-Fecher et al 2012).

The literature is divided over whether the continuing with CDM or a similar program, even with improvements, can play a role in terms of promoting sustainable development. Viewed as a market mechanism, the CDM projects are largely private sector projects with commercial motivations, pitched in a way so as to be able to generate additional revenue from sale of carbon credits. In this perspective, some projects with better co-benefits receive a premium from the buyers, which shows that there is a premium market developed as time going on. If the future potential carbon market mechanism still treats SD benefits as priority, it is important to include this premium market and create motivations to encourage more buyers into this market.

One area that will inevitably require additional development is how to align SD criteria in a way that works with current approaches to national decision-making authority. National sovereignty considerations drove the existing nation-based SD arrangement and has hindered a consistent agreement on SD criteria. The record of CDM on delivering co-benefits has varied across countries in part because countries have different interpretations of these benefits. The absence of internationally agreed criteria for sustainable development, or processes to assess local co-benefits, creates obstacles to improving sustainability outcomes. Some literature suggested that national sovereignty considerations could be incorporated via an international standard created with national inputs (Uddin et al 2007, Olsen and Fennhans 2008, Boyd et al 2009, Corbera et al 2009, Macdonald 2010, Cole and Roberts 2011, Spalding-Fecher et al 2012, Arens et al 2015, Olsen et al 2015, Horstmann and Hein 2017). As a result, any interventions of establishing international criteria would take account of a host country’s views on sustainable development.

4.4. Looking forward

There is agreement that scaling-up the participation of developing countries, especially LDCs, to a decarbonized global society can be done by, in part, by investing in local capacity building and including perspectives and input from local communities.
Probably the most salient current discussion about future mechanisms that blend carbon finance with sustainable development goals has been catalyzed by Article 6 of the Paris Agreement, which allows the possibility that nationally determined contributions (NDCs) could be achieved with market approaches. Experience and lessons learned from the CDM can inform these discussions.

Article 6 suggests the creation of two market-based mechanisms and one non-market mechanism. The first market-based mechanism, called ‘Cooperative Approaches (CAs)’, is defined in Article 6.2 and 6.3. It is a voluntary bilateral market mechanism, enabling countries to use so-called International Transfer of Mitigation Outcomes (ITMOs) to deliver both the NDCs and sustainable development. The second market-based mechanism, the Sustainable Development Mechanism (SDM), is a framework under the international oversight defined in Article 6.4–6.7. Both CA and SDM were created such that a Party retains national discretion whether to use either one (Stavins and Stowe 2017). The third, non-market approaches to promote mitigation and adaptation while contributing to sustainable development is defined in Article 6.8–6.9. This non-market approach covers from promoting mitigation and adaptation, to enhancing participation from both public and private sectors, to enabling coordination across instruments and institutions.

Article 6 mirrors some core ideas of the CDM, with the CDM institutional structure forming a potential basis for developing the SDM rulebook (Michaelowa 2016). Both Article 6 and the CDM focus on promoting sustainable development while cutting emissions to support each country’s target or NDC. And just as for the CDM, Article 6 also places sustainable development as the parallel goal as the mitigation outcomes. There is a strong echo of Article 6 from the Kyoto Protocol in that it emphasizes the importance of the real, measurable, and long-term benefits related to the mitigation of climate change (UNFCCC 1997, 2015). The CDM focuses on project-level sustainable development benefits from emission reductions, while Article 6 refers to sustainable development benefits generated from the level of the whole mechanism (Olsen and Soezer 2016).

Broadly, Article 6 as a whole goes beyond the CDM’s domain of projects and programs and will focus on the entire country. One of the most frequent and consistent suggestions from experts and scholars is to adopt a sectoral crediting mechanism. Instead of using a project-based format which creates inconsistency, a sectoral approach should enable the host countries to have a better idea of the overall emission trend for the whole sector rather than the single projects (Greiner and Michaelowa 2003, Ellis et al 2007, Muller 2007, Alexeev et al 2010b, Partridge and Gamkhar 2010, Mills and Jacobson 2011, Erickson et al 2014, Purdon 2015). It is thought that policy approaches available to governments could enable them more effectively to reduce emissions across sectors. Were this to be the case, engagement from the host countries would also scale up to the sector level. The wording of Article 6 makes this transition from a project-based mechanism sector or country-based crediting mechanism possible (Stavins and Stowe 2017).

Article 6 is, on the other hand, similar to the CDM in its ability to provide financing in ways that are additional and complementary to existing financing or funding mechanisms. In doing so, it provides an opportunity to scale up emission reductions and expand market participation by engaging developing countries on both the investor and project side. Moreover, one of the CDM’s strengths was its inclusion of a novel way for investors to support low-carbon investment in developing countries while minimizing delivery and currency risk (Bodnar et al 2018). This north to south financial flow—in the case of CDM—has provided some lessons. As financial flows become multi-directional (i.e. not just north-south, but also south–south) (Jachnik et al 2017) additional resources for climate change will be unlocked. As this is done, engaging a wider number of investing countries will be essential to ensure that local co-benefits are valued and supported through any new mechanism.

Our review has demonstrated that, while CDM experience was heterogeneous in its ability to deliver community co-benefits, those benefits were more likely to manifest in projects following general best practices for finance, including significant community consultation and engagement in the planning and implementation process. Discussions on any new system focused on sustainable development within respective national systems should also address the more specific question of how such a mechanism would support local co-benefits. While undoubtedly the challenge of nationally mediated sustainable development criteria will remain in some form, opportunities do exist for providing guidelines for how to include these considerations in any new approach.

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Data availability statement

Data sharing is not applicable to this article as no new data were created or analysed in this study.
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