Vulnerability of CDM Projects for Discontinuation of Mitigation Activities

Assessment of Project Vulnerability and Options to Support Continued Mitigation

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List of Abbreviations

BAU	Business as usual (continuation of current unabated trends)
CAPEX	Capital expenditure
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CFL	Compact florescent lamps
COD	Chemical oxygen demand
CPA	Component Project Activity (of a CDM PoA)
EFB	Empty fruit bunches (from palm oil processing)
ETS	Emissions trading scheme
FIT	Feed-in tariff
GDP	Gross domestic product
GHG	Greenhouse gas
GNI	Gross national income
GS	Gold Standards (label and crediting programme)
ICL	Incandescent lamp
JCM	Joint Crediting Mechanism (Japanese programme)
LED	Light emitting diodes
LPG	Liquid petroleum gas
OPEX	Operating expenditure
PAT	Perform, Achieve, Trade programme in India
PDD	Project design document
PMR	Partnership for Market Readiness (World Bank Initiative)
PoA	Programme of Activities (CDM project modality)
POME	Palm oil mill effluent
PPA	Power Purchase Agreement
REC	Renewable Energy Certificates
USD	United States Dollar (currency)
VCS	Verified Carbon Standard
VER	Verified Emission Reduction (voluntary market credit)

1 Introduction

Situation of carbon market mechanisms within international climate negotiations

Despite its previous successes and achievements, the global carbon market finds itself currently in a critical and uncertain period. The large number of mitigation activities initiated through the two most important project based carbon market mechanisms - the Clean Development Mechanism (CDM) and Joint Implementation (JI) - has led to an increasing supply of emission reduction credits, which in recent years has superseded the limited demand for such credits considerably; demand has tailed off considerably due to the global economic crisis as well as the inability to conclude a new major international climate change agreement in 2012 with ambitious mitigation targets and a clearly defined role for flexibility mechanisms.

Such discourse between supply and demand has had a dramatic effect on the price of carbon, which has plummeted in recent years. This market price collapse, amongst other challenges, has consequences for market and investor confidence, current actors in the market mechanisms, and future potential uses for global market mechanisms.

Recent analysis from NewClimate Institute shows that the large majority of CDM projects continued to operate their mitigation activities in 2014, although the majority no longer had a financial incentive to invest in verification and issuance of credits. Therefore, most of these projects operate without the support of market mechanism finance, and there is a considerable risk of project discontinuation for some project types.

The 2015 Paris Agreement includes intended mitigation actions for the post-2020 period for 190 Parties to the Convention. In addition, Article 6 of the Paris Agreement set the foundations for a role for market and non-market mechanisms in the implementation of the Paris Agreement, introducing the term International Transfers of Mitigation Outcomes (ITMOs). The specific role and modalities of mechanisms referred to by Article 6 remain unclear and will be elaborated in future international negotiation sessions.

The Paris Agreement, and Article 6 in particular, provide hope for the future of global carbon markets in general and the stakeholders involved in already implemented project activities. However, considerable uncertainty remains regarding how concrete the role of international market mechanism for the Paris Agreement will actually be, as well as regarding the prospects of the markets before 2020, and the prospects of the mitigation activities already implemented and supported by these markets.

Research objectives and structure of report

This study forms part of a broader project, supported by the German Environment Agency (Umweltbundesamt, UBA), with the primary objective to analyse the current situation and development of the international carbon markets.

This report investigates the current situation of existing project-based carbon market activities in the transitional period until a new climate agreement becomes effective after 2020. For the analysis of this undertaking, the focus is laid on existing projects under the CDM due to the broad range of project types pursued under the CDM and the consequential relevance of this analysis for other project-based carbon market activities. Based on a qualitative situational analysis of different CDM project types in the context of the risk of discontinuation of GHG abatement activities, options for their potential continuation and the implications of interventions are discussed.

The contents of this report address three key research questions.

(1) To what extent are existing CDM projects at risk of the discontinuation of GHG abatement activities?
Section 2 presents a methodology for the assessment of the risk of project discontinuation in the face of no CER revenues. In section 3, this assessment methodology is broadly applied to all major project types, before specific project types within specific countries are then selected for more detailed analysis. Section 4 briefly presents the country contexts for the seven focus countries. Sections 5, 6 and 7 present the detailed analysis of project discontinuation risk for the three selected major project types – methane avoidance, biomass energy and household energy efficiency – , included a total of eight project sub-types.

(2) What is the potential GHG abatement impact, compared to the current status quo, of supporting the continuation of different types of existing CDM projects?
Section 8 presents an assessment of the potential impact of support for project continuation on overall mitigation outcomes, focusing on projects deemed in the previous sections to be at a higher risk of discontinuation. The analysis considers the direct emission reduction potential, recognising that discontinuation scenarios may no longer be a simple reflection of pre-project baseline scenarios. Other aspects are also discussed including the relationship between the activity and international climate pledges, potential for perverse incentives in policy making, and transformational change potential of the activity.

(3) What are options to ensure the short- and long-term continuation of existing CDM projects that are at risk of stopping GHG abatement?
For project types deemed to have high risk of discontinuation, and for which the continuation of activities might result in enhanced mitigation outcomes, Section 9 discusses the suitability of various support options, from the angle of practical feasibility and effectiveness for barrier removal. Different types of support instruments and mechanisms are considered including options under international market mechanisms, domestic market-based and carbon pricing mechanisms, and unilateral or internationally supported domestic policy measures.

The results of this research report may have high relevance for international negotiations on the development of international market-based mechanisms, both pre-2020 and for the implementation of the Paris Agreement post-2020. Through the identification of vulnerable projects and the appraisal of suitable channels for supporting their continuation, this report is also highly relevant for those interested in the status of existing market activities in the pre-2020 transitionary period, and for the design of support schemes for pre-2020 mitigation action.

2 Methodology for Assessment of Project Discontinuation Risk

This section presents an overview of the methodology developed and applied for the assessment of project discontinuation risk. Approaches for other research components, including the selection of project types and countries for analysis, the assessment of the mitigation impact for providing support to vulnerable projects, and the assessment of policy options for the continuation of mitigation at those projects, are all discussed within their respective sections of the document, where the approaches are also applied.

Overview of methodology

The analysis for WP1.1 and WP1.2 requires a consistent approach for the determination of the vulnerability of specific project types for the discontinuation of the project mitigation activity. This section outlines the methodology developed and the steps implemented for this assessment.

The methodology employs a systematic approach in order to assess the likelihood of project continuation, for any given project, based upon factors including local regulations, economic benefits and costs, non-financial barriers and other conditions.

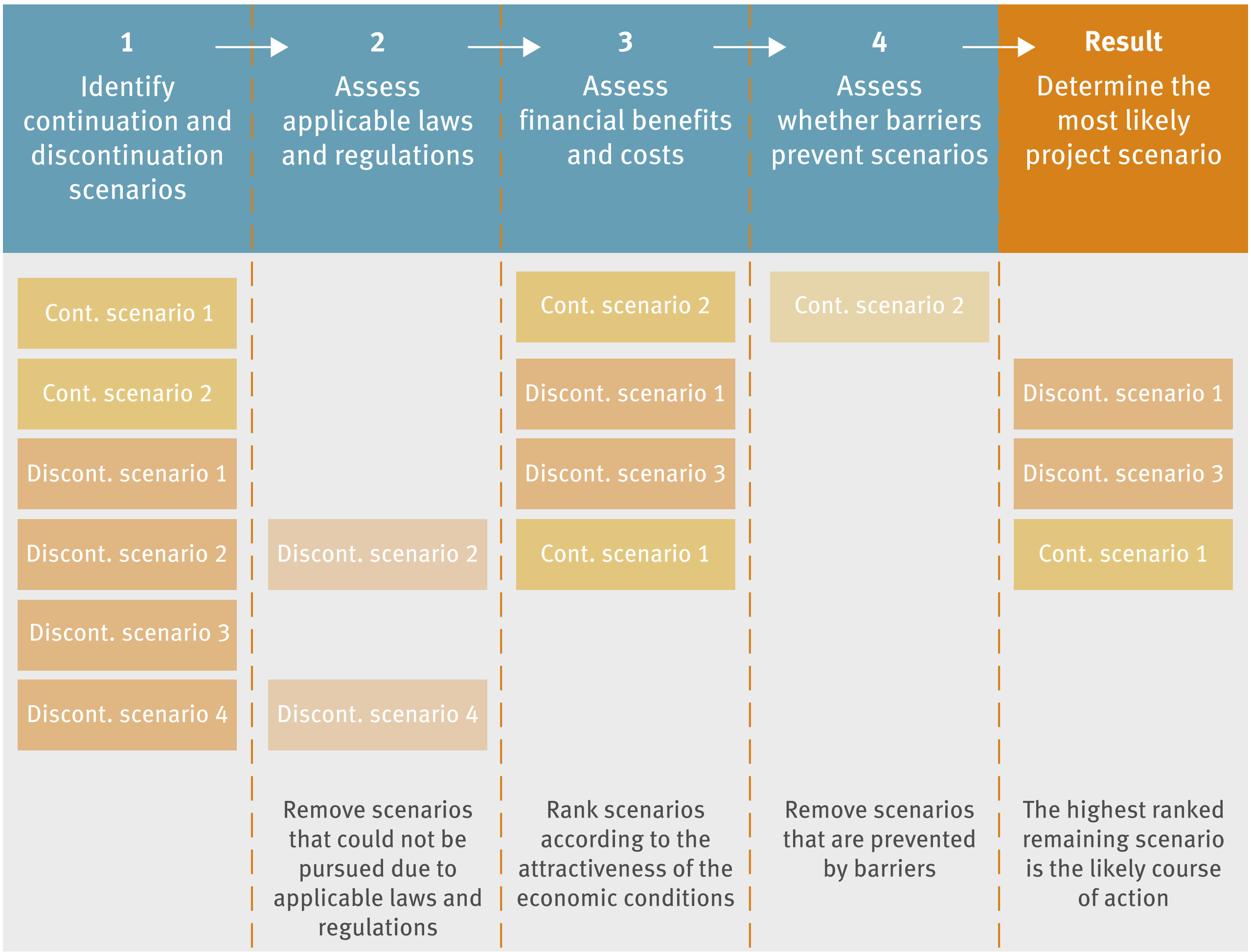
The methodology is applied to categories of project types, as identified in section 3.1 below, and not to individual projects. This implies that the typical conditions and circumstances of the relevant project category are considered, but that differences between and specific circumstances of individual projects cannot be fully reflected. This bears limitations for the results for our analysis: the findings are likely to hold for most of the projects in the category, but individual projects may face different conditions and may hence have a different vulnerability for project discontinuation.

The assessment methodology presented in this section, and applied in sections 5, 6 and 7 assesses the vulnerability of the original CDM project activity only; it does not extend to an assessment of the potential mitigation impacts of alternative discontinuation scenarios in the case that the original project mitigation activity is stopped.

The approach used to assess the potential mitigation impact of discontinuation scenarios, where they are assessed to be likely, is presented and applied in section 8.

The assessment of vulnerability of project discontinuation takes as a starting point the assumption that the project owners do not have any CER revenues, which is a reality for many projects under current market conditions. The assessment of project discontinuation vulnerability considers only the situation of projects at the current point in time. Whether the economic conditions favour continuation of the activity or not in the absence of CERs at the present time is not in any way a reflection or even an indication of the additionality of projects at the point of their inception. Furthermore, it needs to be considered that the additionality demonstration does not only contain financial analyses but also takes into account other barriers preventing the project implementation like investment or technological constraints.

The methodology is illustrated in the stepped decision chart in Figure 1. The methodology for the individual steps is discussed beneath.



Source: Author, based on Schneider & Cames (2014)

Figure 1: Decision chart used for the assessment of the risk that different CDM project types stop GHG abatement.

Step 1: Identify continuation and discontinuation scenarios

The first step is to map out the various scenarios that could play out for the project, based on its current situation.

Step 1 in Figure 1 shows that two types of scenarios are mapped:

- *Continuation scenarios:* these are scenarios under which there is a continuation of the same mitigation activity that was implemented in the original CDM project. These scenarios do not require the continuation of the CDM project administration, and may involve different stakeholders and participants from the original CDM project design, but the type of mitigation equipment is the same, and it is applied at the same source of emissions.
- *Discontinuation scenarios:* these are scenarios in which the mitigation activity implemented in the original CDM project is no longer pursued. It includes projects where emission reductions stop completely, as well as projects where alternative scenarios may lead to emission reductions elsewhere. For example, a discontinuation scenario for a biomass energy project may be that the biomass is rather sold for other purposes; these other purposes may entail emission reductions. The extent to which discontinuation scenarios may lead to emission reductions elsewhere is investigated in section 8 in a separate exercise for projects where a discontinuation scenario is deemed likely.

The continuation scenarios include the plausible forms in which the mitigation activity could be envisaged to continue, separating potentially important conditions related to technologies or stakeholders into different scenarios. For example, for manure management projects, the situation in which biogas is captured and flared is identified as a separate continuation scenario to the scenario that biogas is captured and utilised for energy generation. In another example, for energy efficient lighting, the situation in which defective lights are replaced by the project owner is identified as a separate continuation scenario to the scenario that the individual households replace defective light bulbs themselves.

Plausible scenarios are identified based on a combination of PDD analyses, from which some pre-project alternative scenarios may still be relevant, insights from interviewees and literature review.

Step 2: Assess policy landscape

The second step is the identification of laws and regulations in the host countries which might have a direct influence on the conditions of the project activity and the feasibility of the identified scenarios.

Scenarios that are deemed not compliant with laws and regulations in the host country are removed from the further analysis. The analysis could take consideration of the extent to which such regulations are implemented and enforced. For the sake of the efficient analysis in this study, enforcement or coherence of regulations is not considered: even in the case that regulations are not enforced, project owners with a medium-term outlook may be inclined to choose scenarios that comply with regulations as they are likely to perceive that the regulations will lead to enhanced enforcement in the medium-term. Furthermore, the identification of projects that may discontinue because they choose to not comply with regulations is not considered a priority for this specific study, since the eligibility of such projects for enhanced support is not certain. In practice, the implications of this methodological decision for this study are limited: none of the identified scenarios for any of the biomass energy project types studied are affected by regulations in any of the focus countries, nor for cooking stoves, whilst the number of scenarios affected by regulation in other project types is very small.

Step 3: Assess financial benefits and costs

In a third step, the remaining scenarios are ranked according to the attractiveness of the economic conditions entailed by the scenario.

The additional costs and potential benefits of the activity are first mapped out for each of the scenarios. The costs and benefits mapped include only those that are incurred in the future, moving forward from the current situation of the project activity; past costs such as sunk upfront investments not considered, as they are usually irrelevant to the rational economic decision making on how to proceed in the current situation.

This includes previously committed costs, such as ongoing debt, which may usually be considered sunk in that they are committed and fixed for all conceivable scenarios.[1]

Moreover, the costs and benefits analysed are those which are *additional* to the costs and benefits that occur anyways under *all* plausible scenarios. For example, in the scenario that biogas is captured from manure management at a livestock farm, operating costs might be incurred for collection of the manure and operation of the bio-digester; only the costs of the bio-digester operation would be included in the analysis, in the case that either regulatory or practical issues ensure that the manure is collected in all plausible scenarios, so costs for such processes do not affect the comparative feasibility of the options.

The costs analysed include any relevant additional costs that can be identified, including operation costs (e.g. staffing, land rental and inputs), maintenance costs (e.g. equipment repair and part replacements), and any other appropriate costs. Benefits are highly variable across project types and scenarios, but might include for example benefits from direct revenues due to sale of energy or materials, or cost savings due to the own use of energy or materials.

In the case that the cost and benefit mapping exercise shows that a scenario has costs with no benefits, the economic conditions for that scenario can be deemed to be *negative*, without further analysis into the extent of the costs. In other cases, further analysis is required to determine whether the benefits are likely to be in excess of the costs, and whether the net benefit is likely to be in excess of that from other scenarios.

For scenarios which closely resemble those analysed in original project design documents, the investment analyses (IAs) included with PDDs are used as a basis for initial indications on the likely trade-offs between the costs and benefits. The element pertaining to the initial capital investment in these IAs is excluded from consideration, while the remaining relevant costs and benefits are incorporated into the analysis. For this study, this approach was taken for all continuation and discontinuation scenarios that matched very closely, under their present conditions, the scenarios presented in PDDs. The number of analysed PDDs was determined by the project research team according to the clarity of the trends that prevailed; for project types with high homogeneity where IAs reported very similar outlooks, fewer IAs were analysed than for project types where a greater diversity in conditions required the analysis of more projects to form a clear picture of the emerging trend[2]. A more scientific approach to the number and specific selection of PDDs to be analysed was deemed unnecessary for this study, since the analysis of PDDs was to serve the purpose of assessing the general vulnerability to discontinue project implementation, rather than assessing the precise costs and benefits.

In the case that the analysis of the IAs provided a very clear and homogenous trend, the data from IAs formed the basis for the conclusion of the economic conditions. However, in most cases, the analysis of IAs did not lead to clear conclusions on their own, due to highly diverging conditions of projects within project types, only marginal differences between the analysed costs and benefits, or the fact that key assumptions and prices in some older IAs might be suspected to be out of line with the current market situation. In those cases, the analysis of the IAs was used only for the purpose of providing initial indications.

For scenarios that deviated from those already analysed in IAs, or for which the data from IAs were deemed only suitable to provide an initial indication, further information was obtained on the economic conditions from interviews with local experts (see acknowledgements), and literature review. This was the case for most scenarios studied.

1 Forcing bankruptcy in order to default on loan liability may be a viable option for some project owners in the case that the CDM project activity is the only or major activity of the business (e.g. renewable energy power plant), rather than being built into a wider economic activity (e.g. fuel switch or improvements at industrial facilities or farming operations), although it is uncertain to what extent this may be viable – the specific credit conditions of projects and the securities attached are entirely case specific and may not be analysed at the level of project types – and even in the case that such an approach is viable it is unclear if this may have any impact on project continuation; the economic prospects of the project moving forwards do not change, but rather it would be the responsibility of the bankruptcy manager or the credit institute to determine the most attractive option for moving forwards; speculation of outcomes at the project type level, in this regard, are not possible.

2 The IAs for up to 40 project types were analysed for the most variable project subtypes, whilst for the project types with particular homogeneity fewer than ten projects were analysed to determine a common trend.

Step 4: Assess whether barriers prevent scenarios

This step includes an analysis of how potential non-financial barriers might affect scenarios that are otherwise deemed to have positive economic conditions. For example, project scenarios may face barriers in the form of complex structures for the distribution of costs and benefits, in which the stakeholders that receive the benefits of the scenario are not the same ones as though who entail the costs or who determine the continuation of the activity. Another example is where cultural preferences or information deficits may lead to the benefits and costs of the scenario being not fully appreciated.

Likewise, it is also discussed here in some specific cases, if mitigating factors might increase the plausibility of scenarios deemed to have negative economic conditions. Potential mitigation factors may include, for example, cultural preferences or that the project owner is motivated by other non-financial considerations, perhaps such as research or community development programmes.

The analysis of barriers is quite specific to local contexts and was conducted through interviews with local experts and literature review.

Determination of vulnerability

Following the analysis of barriers, the most economically attractive scenario which does not face insurmountable barriers is considered the most likely scenario. The project type is deemed to have high or low vulnerability dependant on whether the likely scenario is a discontinuation or continuation scenario.

3 Selection of Project Types and Countries for Analysis

The conditions of project-based market activities vary considerably between project types, regions and individual countries. For example, the current rate of regular operation of the GHG abatement activity for existing CDM projects is understood to vary considerably, from 48 % of methane avoidance projects to 93 % of own generation energy efficiency projects. The variation between countries is even more prominent; just 26 % of existing CDM projects in Mexico are understood to have been operating their GHG abatement activity in a regular fashion in 2014, compared to 89 % of projects in China (Warnecke, Day, & Klein, 2015, Chapter 4.1). Even the conditions and outlook of specific project types vary considerably between regions; some of the best performing project types in Asia, in terms of continued rates of regular operation, were among the worst performing project types in other regions, due to lack of supporting regulatory conditions, and due to not being targeted for international support schemes (Warnecke, Day, & Klein, 2015, Chapter 5.1). Therefore, the key research questions of this undertaking must be addressed through the analysis of specific project types, within national contexts; an analysis of the CDM as a whole would result in broad outcomes that contain too many granular variations to be of practical use. The analysis of all project types and countries is beyond the scope of this research, and particular project types are understood from previous research (Schneider & Cames, 2014; Warnecke, Day, & Klein, 2015) to be much more relevant to considerations surrounding the risk of project discontinuation and potential support mechanisms, than others. Likewise, the considerable differences between countries regarding their economic backgrounds and their historical participation in international carbon markets make some countries particularly more interesting than others, especially for some specific project types.

A selection of three project types was carried forward for in-depth analysis, to discuss the three key research questions of work package 1. A starting point for the selection was to focus on project types that:

- Are of key importance for climate change mitigation and market-based approaches worldwide.
  - Relate to major emission sources, and entail significant emission reduction potential.
  - Account for a high volume of global market activity.
  - Are of relevance in all major regions.
- Have a medium or high risk of discontinuing emission reduction activity under a continuation of current market conditions.
- Are expected to have relatively good availability of data/information.

A pool of eight countries was selected for the contextual analysis of these project types. For each project type, the most relevant countries from the pool of eight are analysed. The selection process was designed to target countries with the following characteristics:

- Middle income
- Significant importance for global market developments
- Significant importance for global greenhouse gas emissions
- High relevance for the selected project types
- Relatively good availability of data/information.

Figure 2 presents an overview of the steps for the selection of project types and countries to be analysed in work package 1.

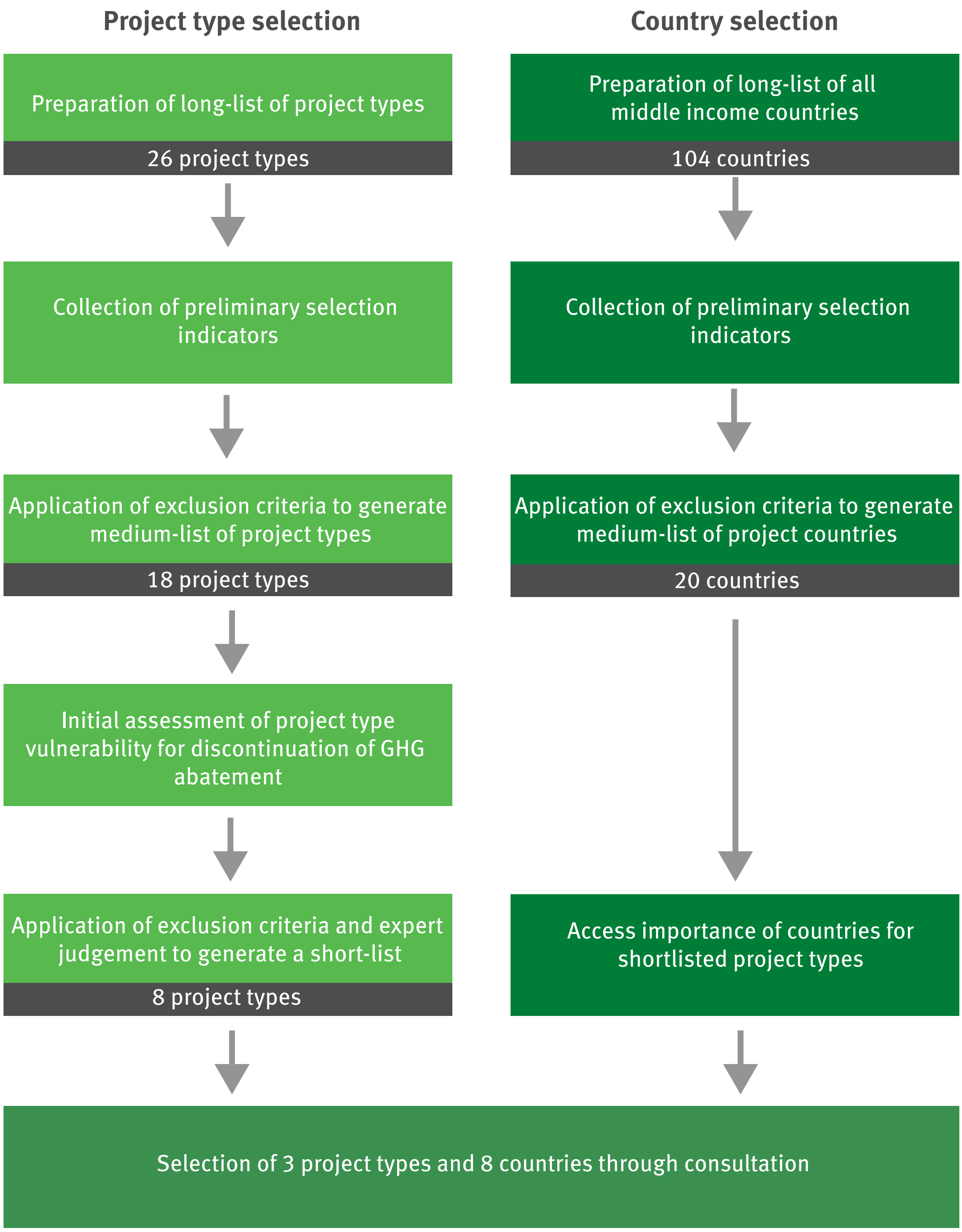


Figure 2: Overview of steps for selection of project types and countries

3.1 Selection of Project Types

Preparation of medium list of project types

A medium list of project types was generated for which an initial assessment of project type vulnerability was applied.

As a starting point, a long list of all major project types according to the classification of the UNEP DTU pipeline was prepared, including a total of 26 major project types, and data to facilitate a preliminary selection were collected for all of these types. Specifically, the following information for all project types was compiled, based on data from the UNEP DTU compiled CDM and PoA pipelines from January 2016 (UNEP DTU, 2016):

- Total number of registered CDM projects and Component Project Activities (CPAs) under PoAs (volume of activity under the project type)
- Total accumulated expected emission reductions between 2013 and 2020[3], according to project design documents (PDDs) (emission reduction potential).
- Number of projects in each region (regional distribution of activity)
- Anticipated availability of information (low-medium-high rating). This rating is based on the CDM evaluation in Warnecke et al. (2015). For project types which were covered under this study, the anticipated availability of information is rated good if information could be obtained from over 80 % of the sampled projects from the previous survey, fair for a response rate of over 70 %, and poor for response rates below this. A full list of project types covered by this study, and issues faced in obtaining information are summarised in Warnecke et al. (2015, Chapter 3.2.1). Project types that were not analysed in Warnecke et al. (2015) are unrated in this step.

The list of major project types was adjusted through the application of the following exclusion criterion:

- A project type is excluded if it accounts for *both* less than 0.5 % of all global registered CDM projects *and* less than 0.5 % of the total accumulated potential emission reductions up to 2020.

A sensitivity analysis of the exclusion criterion finds that should the values of the exclusion boundaries have been set at 0.3 % instead of 0.5 %, three additional project types would have been included in the medium list: cement, energy distribution and transport. These project types are not of great interest for the purpose of this research:

> **Cement** projects cover a single technology, clinker replacement, in a small number of plants. Such practices are becoming more common and are increasingly addressed through regulations.
>
> **Energy distribution** projects are mostly accounted for by a small number of district heating systems in Europe and Central Asia. Once implemented, these projects are likely bound to long term contracts that require continuation of services, and the withdrawal of CER revenues is unlikely to have an impact on their continuation.
>
> **Transport** projects include a small number of a wide variety of different activities in the transport sector, covering modal shift, enhanced technologies for personal vehicles and biodiesels, amongst others. It is not practical to assess transport projects as a collective group for the purpose of this research.

It is understood that significant differences between project subtypes for the major UNEP DTU project types exist, but these differences will be explored further if the project type is selected for detailed analysis.

The medium list of project types for selection is presented in Table 1.

3 The total accumulated emission reductions expected between 2013 and 2020 (available from the UNEP DTU pipeline) is used as a proxy indicator of the emission reduction potential between 2016 and 2020, which is of primary interest. PDD information for emission reductions in specific years are available from the IGES CDM Database, but the categorisation of project types varies slightly from the UNEP DTU classification, as used in this study. Actual credit issuance is not used in this instance as it is understood to not correlate well with actual emission reductions or emission reductions potentials (Warnecke, Day, & Tewari, 2015).

Table 1: Medium-list of project types for selection

Project type *Including a description of subproject types where appropriate (this does not include an exhaustive list of included subtypes)*	Registered projects (inc. PoA CPAs) No.	%	Abatement potential 2013-2020 (CO_2e)* M t	%	Expected information availability **
Biomass energy Use of biomass-based fuels, such as agricultural and forestry residues, biogas and biodiesel, for energy generation	684	8.0 %	326	4.3 %	Good
Coal mine / bed methane Treatment and/or utilisation of methane from coal mines, including ventilation air methane	86	1.0 %	295	3.9 %	Fair
EE households Lighting, stoves and appliances	417	4.9 %	122	1.6 %	Fair
EE industry Efficiency improvement in industrial plant processes	100	1.2 %	23	0.3 %	Fair
EE own generation Use of process wastes for heat or energy generation	316	3.7 %	309	4.0 %	Good
EE supply side Efficiency improvements of existing energy generation facilities incl. fossil fuel plants, cogeneration and combined cycle projects	70	0.8 %	199	2.6 %	Unrated
Forests Afforestation, reforestation, mangroves and agroforestry	57	0.7 %	20	0.3 %	Unrated
Fossil fuel switch New natural gas plants and switch from oil to natural gas	104	1.2 %	390	5.1 %	Fair
Fugitive Treatment of fugitive gases from oil and gas production	47	0.6 %	183	2.4 %	Unrated
Geothermal	34	0.4 %	73	1.0 %	Unrated
HFCs Treatment of HFC-23 waste gases	22	0.3 %	604	7.9 %	Poor
Hydro	2,152	25.2 %	1,974	25.8 %	Good
Landfill gas Treatment of landfill gas and municipal solid waste including flaring and power generation activities	382	4.5 %	405	5.3 %	Good
Methane avoidance Avoidance, treatment and utilisation of methane from manure, wastewater, palm oil waste and composting	792	9.3 %	197	2.6 %	Good
N_2O Decomposition of N_2O from nitric and adipic acid production	104	1.2 %	467	6.1 %	Fair
$PFCs+SF_6$ Avoidance, treatment or recycling PFC and SF_6 gases	15	0.2 %	38	0.5 %	Unrated
Solar Solar PV, solar thermal and solar water heating	509	6.0 %	131	1.7 %	Fair
Wind	2,480	29.1 %	1,775	23.2 %	Good
Total	**8,371**	**98.1 %**	**7,529**	**98.5 %**	

* Accumulated expected GHG emission reductions 2013-2020 according to PDD information (UNEP DTU, 2016).
** Initial rating of the expected transparency and information/data availability for activities in the respective sectors, based on author's judgement and response rates from project types for the CDM evaluation of Warnecke et al (2015).

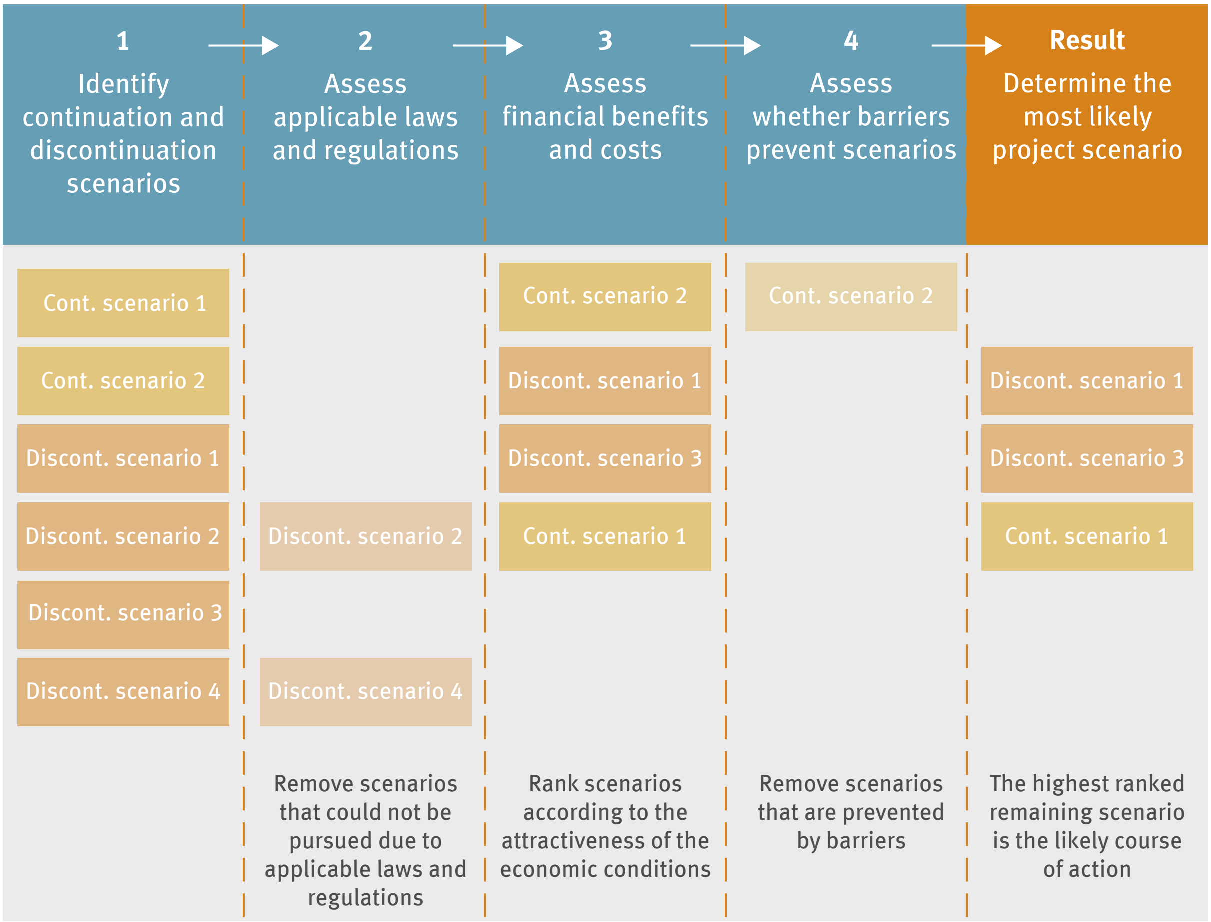
Initial assessment of project vulnerability

In order to inform the selection of project types for analysis, and to provide a starting point for this analysis, a preliminary assessment was conducted to assess the risks of specific project types for the discontinuation of emission reduction activity in the absence of CER revenues, using the decision tree introduced in section 2, and repeated here in Figure 3.

For the initial assessment of vulnerability for project type selection in WP1.1, step 2 of the assessment methodology from the decision tree in Figure 3 was omitted: this step relates to whether safety aspects or national policies are likely to require or strongly incentivise continued GHG abatement. However, since this research activity includes a detailed analysis of political and legal conditions for the selected project types and countries and a discussion on project vulnerability within country contexts, this step was deferred for these stages of the research, and the initial assessment for project selection reflected only the economic considerations from the original methodology.

In the abridged version of the analysis for the initial assessment of project vulnerability, the full assessment laid out in Figure 3 was not executed extensively for all project types. Rather, the conditions and barriers of generic continuation scenarios were considered, to provide an indication of whether the continuation scenarios may be unattractive, in which case the full analysis of the project type including an analysis of all plausible scenarios would be relevant.

The completion of steps in the decision tree of Figure 3 was based upon the results of the previously applied risk assessment methodology in Schneider & Cames (2014), project level data from the CDM evaluation conducted by Warnecke et al (2015), information from project design documents (PDDs), literature review and supplementary expert judgement.



Source: Author, based on Schneider & Cames (2014)

Figure 3: Decision tree used for the assessment of the risk that different CDM project types stop GHG abatement. Source: Author, based on Schneider & Cames (2014)

Table 2 presents a summary of the results from the initial assessment of project vulnerability for the discontinuation of GHG abatement up to 2020 for the medium list of project types, according to the methodology given in Figure 3.

The analysis is an initial assessment only; it looks into the theoretical generalised conditions of project types in limited detail, and will not accurately reflect the conditions of all projects within the groupings. As such, the initial assessment serves the purpose only to indicate which project types may be most interesting for further detailed analysis. A more thorough assessment of project vulnerability is deferred for WP1.2, after the selection of three project types.

Table 2: Summary results for initial assessment of project type vulnerability

Initial assessment of project vulnerability **A list of the major sub-types included is given beneath each project type*. Where the initial assessment relates in particular to the situation of specific project sub-types, rather than a generalised assessment of the major project type, these sub-types are marked in bold.**	
Biomass energy Bagasse power, Palm oil solid waste, Agricultural residues: rice husk, Agricultural residues: other kinds, Gasification of biomass, Biomass briquettes or pellets	**Low – high (variable according to technological and local conditions)** Under unconducive conditions, biomass energy projects could be stopped due to excessive operational expenditures, or because alternative use of the equipment is more profitable. Conditions vary considerably according to the technological differences between the various subtypes included within this category and the specific conditions of individual projects. For example, conditions for collection and use of bagasse for power may be very different than those for palm oil solid waste and various types of agricultural and forestry residues. Local circumstances are also an important factor, such as the penetration of such technologies and waste collection schemes, which may significantly reduce the OPEX, as well as local conditions for grid connectivity, which influence the potential financial benefits. Depending on the type of biomass energy project, alternative usage of the equipment may be possible. For example, in co-firing projects with partial fossil fuel substitution, the substitution can be reversed and may be more profitable, depending on local accessibility and prices of biomass and the alternative fossil fuel.
Coal mine/ bed methane **Coal Mine Methane,** Ventilation Air Methane	**Low** Financial benefits for power generation often exceed OPEX Most coal mine methane projects utilise methane for power generation, thereby incurring cost savings through reducing the use of alternative energy sources. Analysis from a random selection of PDDs indicates that these benefits usually significantly exceed operational expenditure from staffing, materials, repairs and additional water consumption.
EE households Lighting, Stoves	**Low - High (variable according to subtype and local conditions)** Financial incentives may need to be conducive for continuation of abatement for both the project owners and the individual households. The assessment of risk for household energy efficiency projects is made particularly difficult by the limited depth of prior analysis on the actual conditions of these projects. Incentives for continuation must be analysed both for the project operator and the households. Households may incur a cost saving due to reduced electricity use or reduced fuel demand, unless access to electricity and fuel is free. Once the technology is installed there is no operating cost for the technology itself until the end of the technology lifetime. However, for some projects, continued use of the abatement equipment may be reliant on continuous interaction with the project owner for training, maintenance and replacement of faulty or expired equipment. The continued presence of the project owner may therefore be a factor for continued use of the equipment at the household level. For the project owner, OPEX is incurred for staffing and maintenance of a system for monitoring and communicating with households, whilst financial benefits may or may not be accrued, depending on whether the equipment is distributed without charge or sold to households. The continuation of project owners' activities is therefore likely to be variable between individual projects. The potential withdrawal of the project owner may have a negative trend on continued use of the equipment at the household level. The extent of this trend would depend on various factors including the financial benefits at the household level, the perceived co-benefits and the level of training and education. Efficient lighting bulbs must be replaced on an occasional basis, whilst cooking stoves have a longer lifetime; whether or not replacements are an attractive investment depends upon specific local circumstances and the incentives for project owners and households.

EE industry Chemicals, Petrochemicals, Paper, Cement, Iron & steel, Building materials, Non-ferrous metals	**Low** Significant cost savings for end-users with no or low additional operating expenditures. Increased industrial energy efficiency incurs cost savings due to decreased demand for electricity or other fuels. Once installed, energy efficiency measures usually do not incur OPEX or the OPEX is low compared to cost savings. In the CDM Status Report (Warnecke, Day, & Klein, 2015), a majority of projects reported that non-CER financial benefits were „sufficient“ for continuation of the project activity.
EE own generation Chemicals heat, Petrochemicals heat, Cement heat, Iron & steel heat, Coke oven gas	**Low** Significant cost savings for end-users with no or low additional operating expenditure. Increased use of waste products at industrial facilities for electricity generation incurs cost savings due to decreased demand for electricity or other fuels. Once installed, energy efficiency measures do not incur significant OPEX. In the CDM Status Report evaluation, a majority of projects indicated that they could continue abatement after the crediting period without CER revenue and alternative forms of support.
EE supply side Single cycle to combined cycle, Cogeneration, Higher efficiency coal power, Power plant rehabilitation	**Low** Significant cost savings for end-users with no or low additional operating expenditures. Increased efficiency increases the level of power output resulting in increased revenues, and/or decreases the amount of input fuel required resulting in cost savings. Once installed, the energy efficiency measures do not incur significant OPEX. Significant capital investment for equipment renewal up to 2020 is usually not required, and profit cannot be generated from stopping GHG abatement and investing in an alternative.
Forests **Afforestation**, Agroforestry, **Reforestation**	**Low - Medium (variable according to capacity of owner and local legislation)** OPEX can be greater than current revenues but future revenues from harvesting can be significant. Management and protection of the demarcated forested area requires significant resources. Annual revenues in normal years are far smaller than OPEX. For many projects, the first harvesting years also usually generate additional OPEX that may exceed the revenues of the harvest, whilst the larger harvests towards the end of the project cycle (after 20-30 years) generate significant revenues that normally exceed all costs of the project activity for the proceeding years. The continuation of the project for financial incentives depends upon the potential of the project owner to absorb regular losses until the larger harvests, and on the likelihood that the forest area would be felled if not protected by the CDM project operation. Capital expenditure can be recovered where permitted by law by felling the trees early and selling the wood, and by selling the land or using it for other purposes, such as agriculture. However, in some cases, potential CDM revenues originally made the project feasible, and once implemented, its reversibility is prevented by legislation.
Fossil fuel switch New natural gas plant, New natural gas plant using LNG, Oil to natural gas	**Low - Medium (variable according to project subtype and global fuel markets)** New natural gas plants usually generate positive annual returns on OPEX after initial CAPEX. Oil to natural gas switch is sometimes reversible but would require strong financial incentives, which is unlikely for most projects. For new natural gas plants, capital investments are irreversible and annual revenues usually exceed ongoing OPEX. For oil to natural gas switch, either cost savings or increased operating expenditures may be incurred: depending on the project circumstances the new fuel may be more or less cost effective. This is also highly dependent on volatile global oil and gas prices. Depending on the fuel used, the technology switch may be reversible and may be economically rational if the alternative fuel is cheaper. However, given the volatility of global fuel prices, this is an unpredictable investment. Furthermore, non-financial barriers such as informational barriers and technical capacities may also prevent a conversion from natural gas back to oil unless the case for financial incentives is considerably greater.

Fugitive **Oil field flaring reduction, Oil and gas processing flaring reduction, Natural gas pipelines,** Charcoal production	**Low – High (variable according to project subtype)** Financial benefits usually overcompensate for additional OPEX in flaring reduction projects, but not necessarily for natural gas pipelines. For most projects, gas flaring is reduced through recovery for energy generation, which can reduce demand for alternative sources of energy, producing a cost saving. The generation of energy, where applicable, usually offsets the costs of operating the generators. There is no alternative use for the fugitive gases, aside from energy generation, which would generate greater profits whilst ceasing the abatement activity. Natural gas pipeline projects incur considerable OPEX for leak detection equipment operation and maintenance. Whether the financial benefits of the saved gas exceed the additional OPEX or not depends on the specific conditions and non-economic barriers of the individual projects. In some cases, financial benefits of saved gas could be nil, since the project proponent's contract is a fixed operating fee and entirely independent of the gas transmitted and the volume of gas savings.
Geothermal Geothermal electricity, Geothermal heating	**Low** Significant revenues and very low operating expenditures Projects can generate revenues from electricity sales. The OPEX for geothermal facilities is on average very low: assuming a capacity factor of 70 %, the average capacity factor for geothermal in non-OECD regions in 2013 (IEA 2015), the average OPEX for geothermal is slightly lower than USD 0.02/kWh (IRENA 2015). This value is below average electricity sales prices in most countries. Once the geothermal plant is installed there are no alternative options for the use of the facility which generate more profit than its continued operation.
HFCs **HFC-23**, HFC-134a	**High** Continued operation incurs costs yet no significant financial benefit There are only 3 HFC-134a projects with very limited mitigation potential, so these projects are not considered in this assessment. For HFC-23 projects, the process of thermal oxidation requires costs for operation and maintenance of the equipment, whilst there are no significant revenues or cost savings.
Hydro Run of river, Existing dam, New dam	**Low** Significant revenues and very low operating expenditures Projects can generate revenues from electricity sales. The OPEX for hydro facilities is very low: assuming a capacity factor of 41 %, the average capacity factor for hydro in non-OECD regions in 2013 (IEA 2015), the OPEX for hydro ranges from USD 0.005/kWh to USD 0.05/kWh (IRENA 2012). This range is below average electricity sales prices in most countries. Once the hydro plant is installed there are no alternative options for the use of the facility which generate more profit than its continued operation.
Landfill gas Landfill flaring, Landfill power, Combustion of MSW, Landfill composting	**Low – High (variable according to subtype and local conditions)** Continued operation involves costs but accrues no financial benefit for flaring projects, whilst non-CER revenues are sometimes greater than operating expenditures for projects with utilisation of landfill gas and MSW. Projects without utilisation of gas face OPEX but do not generate financial benefits. For projects with utilisation of gas, revenues or cost savings can be produced by energy generation. For these projects, data from a random selection of PDDs shows that, after the initial CAPEX investment, annual non-CER revenues from electricity sales and other financial benefits are significantly greater than annual OPEX. However, practical experiences from landfill gas power projects indicate that potential revenues are often stymied by uncertainties related to the quality of the gas produced by the landfill. Depending on the quality of the input material, equipment may be damaged and require repair or replacement occasionally; whether or not such expenses are economically rational depends on the highly variable conditions discussed. In some cases, partial recovery of CAPEX may be possible, and attractive, through the sale of the electricity generators. For MSW combustion and composting projects, revenues from accepting waste for treatment, combined with financial benefits of utilisation for energy, are normally sufficient to cover OPEX.

Methane avoidance Manure, Domestic manure, Wastewater, Palm oil waste, Composting	**Low – High (variable according to subtype and utilisation of wastes and methane)** Continued abatement is likely to be economically rational for projects that utilise wastes or methane for energy or compost for fertiliser. For projects without utilisation of waste or methane, OPEX is incurred through staffing and maintenance for operation of the equipment whilst often no financial benefits are incurred, or in the case of revenue through water treatment fees or tipping fees they are relatively small. For projects with utilisation of waste or methane, profits or cost savings can be produced by energy generation or through the use of compost for fertiliser. For these projects, data from a random selection of project internal rate of return calculations (IRRs) shows that, after the initial CAPEX investment, annual non-CER revenues from electricity sales or cost savings from reduced electricity expenditure are usually greater than OPEX.
N_2O Adipic acid, nitric acid	**High** Continued abatement involves operating expenditures but no or very low financial benefits Abatement of N_2O from both adipic and nitric acid plants involves operational or new capital expenditures for regular replacement of catalysts or fuel costs in the case of thermal abatement. Nitric acid projects do not generate financial benefits from abatement. Adipic acid projects generate financial benefits from steam generated in the process of N_2O decomposition. However, OPEX may exceed the costs savings from steam generation.
PFCs+SF_6 PFCs, **SF_6**	**Low (AM78)-High (AM35/AM65)** No revenues but additional operating expenditures for projects using methodologies AM35 and AM65. There are only 5 PFC projects, with relatively limited mitigation potential, so these projects are not considered in this assessment. For SF6 projects, no additional revenues or cost savings are obtained from SF_6 projects, aside from minor cost savings from SF6 recycling in projects with methodology AM35 (2 projects). The OPEX of SF6 projects depends on the methodology used. Projects that switch SF_6 for other gases (AM65) incur minor additional costs for the more expensive gas, as well as major additional costs for operation and maintenance of the equipment using the new gas. For projects that recycle SF_6 gas (AM35), there is additional OPEX for the recovery and recycling equipment. For projects that abate emissions using an abatement device (AM78), there are no OPEX, and no alternative option that generates more profit through the removal of the abatement device.
Solar **Solar PV,** Solar thermal power, Solar water heating, Solar cooking	**Low** Non-CER revenues are usually greater than operating expenditures Solar PV projects, which account for 90 % of all solar projects, can generate revenues from electricity sales. Continued operation of the installations requires staffing and maintenance: the cost of solar power generation per kWh varies greatly according to local conditions including the solar resource potential in the specific area, but a majority of solar projects reported in the CDM Status Report evaluation that they could continue regular operation outside of the CDM and without alternative support. The conditions of other types of solar projects, such as solar water heaters, may vary from the conditions for solar PV. These account for a small proportion of the solar category, but are considered highly important project types in terms of the wider benefits they can deliver.
Wind	**Low** Non-CER revenues are usually greater than operating expenditures Projects can generate revenues from electricity sales. Continued operation of the installations requires staffing and maintenance: the cost of solar power generation per kWh varies greatly according to local conditions including the wind resource potential in the specific area, but a larger than average proportion of wind projects reported in the CDM Status Report evaluation that they could continue regular operation outside of the CDM and without alternative support.

Sources: Authors' own judgement, Schneider & Cames (2014), data collected for the CDM Status Report (Warnecke, Day, & Klein, 2015), IEA (2015c), IRENA (2012), IRENA (2015b), Schneider et al. (2010)

* List of major project sub-types included in the category is for information purposes and includes sub-types that account for over 90 % of the projects and abatement potential in the project type

Generation of short-list of project types

From the medium list of project types, a short-list of eight project types was generated through the application of exclusion criteria:

- The project type is excluded if the initial assessment of project type vulnerability indicates that the project type is at a low risk of discontinuation of GHG abatement. As per the summary of the initial risk assessment in Table 2, this excludes the following project types: coal mine/bed methane, industrial energy efficiency, own generation energy efficiency, supply side energy efficiency, geothermal, hydro, solar, and wind.
- The project type is excluded if further analysis of the project type is considered to be not feasible due to complexities identified in the initial assessment of vulnerability.
  - Oil to natural gas fuel switch projects have a low-medium rating, but account for less than 10 % of the abatement potential of all fossil fuel switch projects, and the specific conditions under which a reversal could be economically attractive are dependent on volatile and unpredictable oil and gas prices. From a broader perspective, these project types offer limited value for achieving long-term technology transformation, since they use transition technologies that involve the continuation of fossil fuel combustion.
  - Forestry projects have a large variation of conditions between individual projects, creating difficulties for the potential analysis of these projects as a collective group. A number of stakeholders, who require different types of incentives, are involved in the continued operation of such projects. Forestry projects continue to receive a great deal of research attention for potential support mechanisms outside of the CDM.

As such, eight project types were shortlisted for consideration for selection: biomass energy, household energy efficiency, fugitive emissions, HFC-23, PFCs and SF6, landfill gas, methane avoidance and N20. The conditions and the initial assessment of vulnerability for these project types are summarised in Table 3. For completeness of information, an indication of potential impacts for human development and long term transformation are also included in the table. These ratings are subjective assessments based on the experience and judgement of the authors.

Table 3: Summary of shortlisted project types

Project type	Number of projects[1]	Abatement potential (% of CDM)[2]	Long term transformation impact[3]	Human development impact[3]	Information availability[4]	Initial assessment of project vulnerability for discontinuation of abatement activity[4]
Biomass energy	684	4.3 %	High	Low-High	Good	**Low-High:** Projects could be stopped due to excessive OPEX, or because alternative use of the equipment is more profitable.
Fugitive	47	2.4 %	Low	Low	Unrated	**Low-High:** Financial benefits usually cover additional OPEX in flaring reduction projects, but not necessarily for natural gas pipelines.
Household energy efficiency	417	1.6 %	High	High	Good	**Low-High:** Financial incentives may need to be conducive for continuation of abatement for both the project owners and the individual households.
HFCs	22	7.9 %	Low	Low	Poor	**High:** Continued operation incurs costs yet no significant financial benefit.
Landfill gas	382	5.3 %	Low	Medium	Good	**Low-High:** Continued operation is expensive and accrues no financial benefit for flaring projects; revenues are sometimes greater than OPEX for projects with utilisation of landfill gas and MSW.
Methane avoidance	792	2.6 %	High	Medium	Good	**Low-High:** Continuation is likely to be rational for projects that utilise wastes or methane for energy or compost for fertiliser.
N_2O	104	6.1 %	Medium	Low	Fair	**High:** Continued abatement involves operating expenditures but no or very low financial benefits.
PFCs and SF_6	15	0.5 %	Medium	Low	Unrated	**Low-High:** No revenues but additional operating expenditures for projects using methodologies AM35 and AM65.

[1]The number of projects is considered high if accounting for at least 2 % of the CDM population, and low if accounting for less than 1 %
[2]The abatement potential between 2013 and 2020 is considered high if accounting for at least 4 % of the CDM population, and low if accounting for less than 1 %
[3]Long-term transformation impact and the human development impact are subjective assessments based on the judgement of the authors. Project types are considered to have low long term transformational impact if they reduce the emissions of activities that are not understood o be sustainable in the long-term future, such as projects related to the fossil fuel industry.
[4]Information availability is based on authors' judgement and response rates from CDM Evaluation (see Warnecke, Day, & Klein, 2015)

Final project type selection

From the shortlisted project types in Table 3, three project types were selected for the detailed analysis of work package 1, following consultations between the project team and DEHSt:

Biomass energy, household energy efficiency, methane avoidance.

The selection was based on the following reasons for the exclusion of the remaining project types:

- For PFC and SF6 projects, the high vulnerability is considered to apply only to projects using specific methodologies (AM35 and AM65), which includes a total of only 5 projects. PFC projects and the remaining 5 SF_6 projects using alternative methodologies, are deemed to be at relatively low risk of discontinuation. Although the abatement potential of the individual projects is considerable, the quantity of projects is so low that the combined abatement potential is not great.
- Although N_2O and HFC projects are understood to have particularly high vulnerability, and a high abatement potential, various studies have focused extensively on these project types. Furthermore, some support schemes have recently been made available, for which these project types – except N_2O from adipic acid – are eligible[4].
- For fugitive projects, only natural gas pipeline projects are assessed as having a high vulnerability. There are just 14 projects within this sub-type, representing approximately a third of the mitigation potential and project numbers in the fugitive category. Most of these projects are from the Europe and Central Asia region, which does not allow for cross-regional analysis. The Europe and Central Asia region is also of very low relevance to the remaining shortlisted projects.

Landfill gas was also considered an interesting project type for potential analysis, but was not prioritised ahead of the selected three project types. Landfill gas could be considered for analysis in future research.

3.2 Selection of Countries

Preparation of short list of countries

A long list of 104 countries was prepared including all middle income countries, according to the World Bank classification which includes all countries with a GNI per capita for the current fiscal year of 2016 between USD 1,046 and USD 12,736 (World Bank, 2015a).

Next, selection indicators were compiled for all countries in order to determine suitability for analysis. The following specific information was collected for all middle income countries:

- Population and GDP (indication of importance for global carbon market and technology market developments)
- Total volume of currently registered CDM projects (indication of importance for global carbon pricing and market developments)
- Annual GHG emissions (indication of importance for global greenhouse gas emissions)
- Total accumulated potential emission reductions of all existing CDM projects in the country between 2013 and 2020 (indication of importance for global greenhouse gas emissions)

The long-list of middle income countries was adjusted according to the following exclusion criteria:

- Annex I countries are excluded, as they are not eligible to host CDM projects.
- Countries with fewer than 0.1 % of all registered CDM projects are excluded.
- Countries with potential accumulated emission reductions between 2013 and 2020 of less than 0.1 % of the total for all registered CDM projects are excluded.

4 N_2O abatement from nitric acid production are targeted by the Norwegian Carbon Procurement Facility (launched 2013), Germany's Nitric Acid Climate Action Group (launched 2015) and the third auctioning round of the World Bank's Pilot Auction Facility. China has established a domestic policy to support abatement of HFC-23 from HCFC-22 production.

- Countries with *both* fewer than 0.3 % of all registered CDM projects and with potential accumulated emission reductions between 2013 and 2020 of less than 0.3 % of the total for all registered CDM projects are excluded.

A sensitivity analysis of the exclusion criteria indicate that no countries of particular additional interest would be included, should the criteria be relaxed. For example, had the last criterion not been applied, Panama, Guatemala, Laos, Morocco, Dominican Republic and El Salvador would be included. None of these countries have a significant portfolio of projects for the shortlisted project types.

The list of countries for consideration is summarised in Table 4.

Table 4: Short-list of countries for selection, ordered according to number of projects

Country	2014 Population (millions)[1]	GDP 2013 current USD (billions)[2]	2013 total GHG emissions (M t CO_2e)[3]	Registered CDM projects[3]	CDM emission reduction potential 2013-2020 (M t CO_2e)[4]
China	1,364	9,491	8,190	3,906	4,681
India	1,295	1,862	1,524	1,746	758
Brazil	206	2,392	863	352	358
Vietnam	91	171	136	290	134
Mexico	125	1,262	641	225	127
Thailand	68	387	237	161	53
Indonesia	254	910	554	158	123
Malaysia	30	313	193	153	65
South Africa	54	366	380	116	112
Pakistan	185	232	161	90	38
Philippines	99	272	101	77	30
Peru	31	202	63	67	68
Colombia	48	380	154	66	51
Kenya	45	55	22	47	32
Honduras	8	18	10	35	8
Ecuador	16	94	248	33	28
Bangladesh	159	150	46	30	33
Nigeria	177	515	243	25	51
Uzbekistan	31	57	205	15	51
Ghana	27	49	18	11	25

[1](World Bank, 2015b)
[2](World Bank, 2015e)
[3](UNEP DTU, 2016)
[4]Accumulated total of expected GHG emission reductions between 2013 and 2020 according to information from PDDs (UNEP DTU, 2016)

Final selection of countries for analysis

The importance of shortlisted countries for the selected project types was assessed through the collection of the following information for each country:

- Number of projects for each of the short-listed project types in the country
- Proportion of projects from each short-listed project type that are hosted in the country
- Accumulated potential emission reductions of the project type in the country 2013-2020

An overview of the relevance of these countries for the selected project types is given in Table 5. It was determined in discussions between DEHSt and the project team that the 8 countries selected would be **India, Thailand, Malaysia, Pakistan, Mexico, Brazil, South Africa and Kenya**. This selection was based on considerations including broad geographical coverage, relevance of countries for the selected project types, and the anticipated availability of reliable information in the country.

Although initially selected as a focus country, South Africa does not appear in the analysis for this study: whilst it appeared that South Africa may be an interesting focus country due to a small amount of activities in all of the selected project types, South Africa does not have any more than two or three projects in any of the analysed project categories, once they are broken down into logical subtypes in sections 5,6 and 7. It was agreed not to replace South Africa with another country: the only other potential country from Africa for analysis of any of the selected project types was Nigeria which has a moderate number of household energy efficiency projects, yet there are already three countries analysed for household energy efficiency projects including another country from Africa, Kenya.

Table 5: Overview of shortlisted countries for the selected project types

Country	Region	Number of projects (No.) and 2013-2020 abatement potential (M t CO_2e)					
		Biomass energy		Household EE		Methane avoidance	
		No.	M t	No.	M t	No.	M t
India	Asia	294	107	123	37	32	7
Thailand	Asia	27	11	0	0	77	32
Malaysia	Asia	42	37	0	0	89	30
Pakistan	Asia	6	5	53	6	2	0
Mexico	LAC	11	5	27	6	102	28
Brazil	LAC	48	32	0	0	67	28
Kenya	Africa	2	2	18	6	3	1
South Africa	Africa	6	4	6	2	4	1
China	Asia	139	177	20	2	180	46
Nigeria	Africa	1	1	15	5	0	0
Honduras	LAC	5	1	1	0	7	2
Vietnam	Asia	17	5	1	1	23	10
Indonesia	Asia	14	15	0	0	76	29
Philippines	Asia	5	3	0	0	43	8
Peru	LAC	2	0	0	0	2	1
Colombia	LAC	3	2	0	0	5	9
Ecuador	LAC	3	2	1	4	8	2
Bangladesh	Asia	1	0	20	5	2	0
Uzbekistan	Asia	0	0	0	0	0	0
Ghana	Africa	0	0	5	3	2	1

Colour code indicates the relevance of combinations: Green (high) – country has at least 10 % of CDM projects from the project type, or at least 25 projects with an abatement potential of at least 25 M t CO_2e; Yellow (medium) – country has at least 2.5 % of CDM projects from the project type, or at least 10 projects with an abatement potential of at least 5 M t CO_2e; Red (low) – country has at least 0.5 % of CDM projects from the project type; Grey (no relevance) – others.

Next to the list of countries in the left column, a colour code is also used to indicate the final country selection: Green – country selected for analysis; Yellow – country to be considered for back-up; Red – excluded from analysis.

4 Country Contexts

According to the results of the selection process in section 3.2, the analysis of CDM project conditions will focus in particular on projects in India, Thailand, Malaysia, Pakistan, Mexico, Brazil and Kenya. The geographical distribution of these countries is presented in Figure 4.

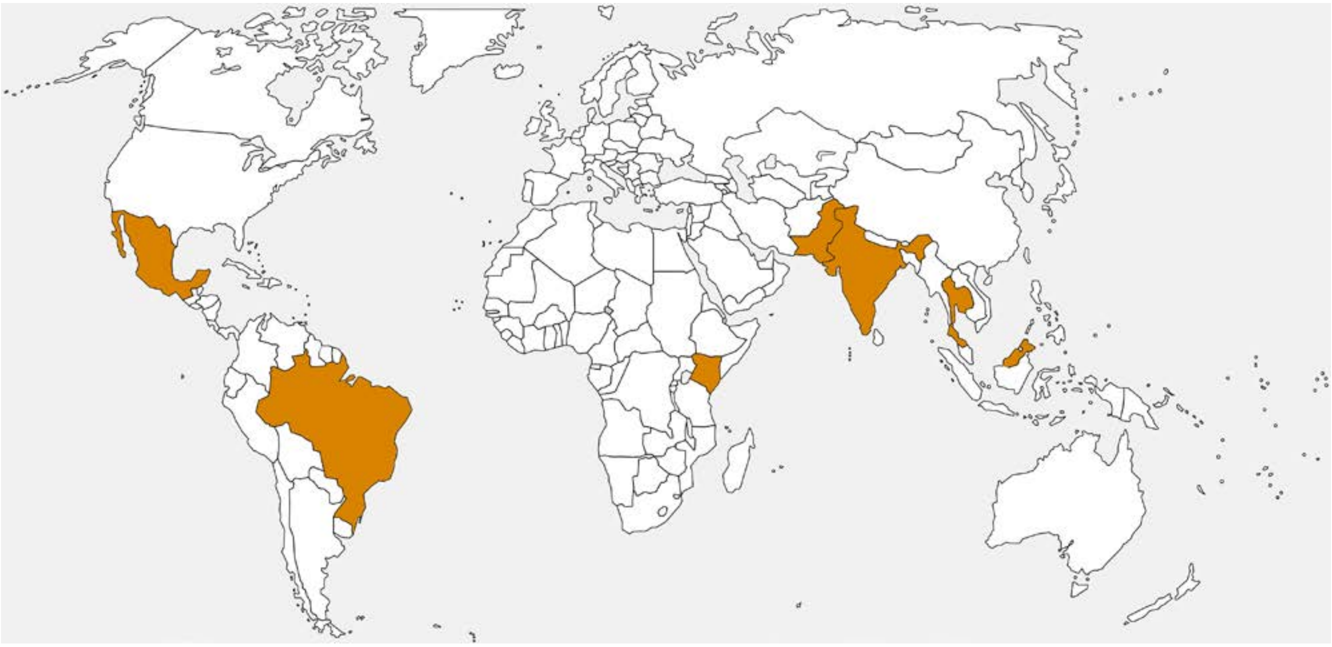


Figure 4: World map showing country selection for detailed analysis of project conditions

In this section, the general national contexts, with relevance for the analysis of all selected project types, are presented in single page fact sheets for each country.

In the country profiles, the following indicators are used to highlight general national context. The years of the data for the country factsheets are those given in the following list, unless indicated otherwise on the country factsheet:

- 2015 population, 2015 population density, 2015 GDP/capita, 2015 poverty headcount[5], electricity access in 2012 (World Bank, 2016)
- Human Development Index in 2014 (UNDP, 2015)
- Total and per capita GHG emissions in 2012 (WRI, 2016)
- Emissions intensity of energy in 2013 (IEA, 2015a)
- Status of activity under the clean development mechanism by January 2016 (UNEP DTU, 2016)

5 Poverty headcount ratio at national poverty lines (2011 PPP) (% of population)

India					
Socioeconomic indicators					
Population	1.311 bn	**Population density**	441/km^2	**GDP / capita**	USD 1,581
HDI	0.6 (Medium)	**Poverty headcount**	21.9 % (2011)	**Electricity access**	78.7%
Greenhouse gas emissions (excluding LULUCF)					
Total	3.013 G t CO_2e	**Per capita annual**	2.4 t CO_2e	**Emissions intensity of energy**	2.41 t CO_2/toe
Clean Development mechanism					
Projects	1,746	**(of which CPAs)**	154	**Abatement potential**	94.8 M t CO_2e
Activities	With the world's second largest portfolio of registered CDM projects, India has a large number of projects from most project types, and the distribution of projects across project types is similar to the average of the whole CDM.				

Other market mechanisms and carbon pricing instruments

Initially authorized in 2008, the Perform, Achieve and Trade (PAT) scheme is a market-based energy efficiency program covering eight energy-intensive sectors. The government expects annual reductions of 100 M t CO_2e (C2ES, 2012). India implemented a pilot ETS for air pollutants in 2011, which controls emissions of SO_2, NOx, and SPM from industrial facilities in three states, without directly controlling CO_2 emissions (IETA, 2015). India's Central Electricity Regulatory Commission established the Renewable Energy Certificate mechanism, requiring distribution companies to purchase a certain percentage of electricity from renewable sources. Revenues from a national coal tax are used partially for the National Clean Energy Fund, which promotes clean energy initiatives and related research. The Partnership for Market Readiness (PMR) supports the expansion of the PAT scheme and the development of an integrated GHG data management system (PMR, 2016).

Climate change mitigation policy

India's INDC includes the targets to lower the emissions intensity of GDP by 33 % to 35 % by 2030 below 2005 levels, to increase the share of non-fossil based power generation capacity to 40 % of installed electric power capacity by 2030 (equivalent to 26-30 % of generation in 2030), and to create an additional (cumulative) carbon sink of 2.5-3 G t CO_2e through additional forest and tree cover by 2030. For 2020, India has earlier put forward a pledge to reduce the emissions intensity of GDP by 20 % to 25 % by 2020 below 2005 levels. The Climate Action Tracker rates the ambition of India's INDC as "medium" (CAT, 2015).

Renewable energy support schemes

The Central Electricity Regulatory Commission (CERC) launched a feed-in tariff in 2009. The feed-in tariff period for most renewable energy technologies is 13 years, extended to 35 years in case of small hydro (‹ 5MW) and 25 years for solar PV and solar thermal. In 2011, the Indian government launched a Renewable Energy Certificates (RECs) programme. Under the Biogas based Power Generation Programme (BPGP), biogas-based power generation pilot projects were established to mature the market for this technology, and subsidies were provided to small-scale project operators to purchase equipment for these technologies (TERI, 2007).

Policy framework

GHG emissions reduction target	✓	**Energy efficiency target**	✓
Renewable energy target		**EE target for buildings**	
RE target for electricity	✓	**Building codes**	✓
Renewable energy support schemes	✓	**Appliances efficiency standards**	✓

Thailand

Socioeconomic indicators					
Population	67.95 m	**Population density**	133/km^2	**GDP / capita**	USD 5,816
HDI	0.72 (High)	**Poverty headcount**	10.5 % (2014)	**Electricity access**	100 %

Greenhouse gas emissions (excluding LULUCF)					
Total	375 M t CO_2e	**Per capita annual**	5.6 t CO_2e	**Emissions intensity of energy**	1.85 t CO_2/toe

Clean Development mechanism					
Projects	161	**(of which CPAs)**	15	**Abatement potential**	6.63 M t CO_2e/a
Activities	CDM projects mostly address waste management and energy efficiency improvement.				

Other market mechanisms and carbon pricing instruments

Thailand is designing a domestic market-based mechanism to reduce energy consumption and GHG emissions in the energy sector with a view to transforming it into an ETS. The PMR supports the development of an Energy Performance Certificate (EPC) scheme and a Low Carbon City (LCC) program for Thailand. Implementation is planned to commence in 2017, for finalization in 2019.
In its INDC, Thailand recognizes the importance of market-based mechanisms and states that it will continue to explore their potentials for achieving sustainable economic growth.

Climate change mitigation policy

Thailand's INDC includes an unconditional target of 20 % GHG reductions from BAU level by 2030. The level of contribution could increase up to 25 %, subject to adequate and enhanced access to technology development and transfer, financial resources and capacity building support through a balanced and ambitious global agreement under the UNFCCC
Additionally, Thailand has a number of energy related strategies such as the Power Development Plan that sets a target to achieve a 20 % share of power generation from renewable sources in 2036. The Alternative Energy Development Plan aims to achieve a 30 % share of renewable energy in total final energy consumption in 2036. The Energy Efficiency Plan aims to reduce energy intensity by 30 % below the 2010 level in 2036.

Renewable energy support scheme

Grid connection for biomass, biogas and other renewable energy projects has been possible under purchase power agreements (PPA) since 2007, with "Adder" rates paid in addition to the wholesale electricity price for the first 7 years. A new FIT programme replaced the Adder programme in 2015, guaranteeing a fixed price to small power producers for a period of 20 years, although projects already selling electricity before 2013 are not eligible to transfer to the new programme (WFW, 2015).

Policy framework			
GHG emissions reduction target	✓	**Energy efficiency target**	✓
Renewable energy target	✓	**EE target for buildings**	
RE target for electricity	✓	**Building codes**	
Renewable energy support schemes	✓	**Appliances efficiency standards**	

Malaysia

Socioeconomic indicators					
Population	30.33 m	**Population density**	92/km^2	**GDP / capita**	USD 9,766
HDI	0.77 (High)	**Poverty headcount**	0.6 % (2014)	**Electricity access**	100 %

Greenhouse gas emissions (excluding LULUCF)					
Total	288 M t CO_2e	**Per capita annual**	9.8 t CO_2e (2011)	**Emissions intensity of energy**	2.33 t CO_2/toe

Clean Development mechanism

Projects	153	**(of which CPAs)**	10	**Abatement potential**	8.1 M t CO_2e
Activities	Malaysia's projects focus largely on the waste sector, biomass energy and methane avoidance.				

Other market mechanisms and carbon pricing instruments

Malaysian projects were included in the annual Japanese Joint Crediting Mechanism (JCM) feasibility studies from 2010 to 2012. Proposed projects included the introduction of air-conditioning control systems for energy reduction and coating fertilizer for N_2O reduction. To date, no projects in Malaysia have been approved for the JCM.

Climate change mitigation policy

Malaysia's INDC includes the goal of reducing GHG emissions intensity of GDP by 45 % by 2030 compared to 2006.
A 35 % reduction target was set unconditionally, while 10 % reduction is contingent on the international provision of sufficient climate financing, technology transfer and capacity building assistance.
The current Eleventh Malaysian Plan (2016-2020) for continuing green growth and carbon footprint reduction is in line with the INDC.

Renewable energy support scheme

Malaysia's overarching policy framework for clean energy development has provided a strong foundation for significant deployment of renewable energy and energy efficiency.
Grid connection for renewable energy projects including biogas and biomass has been possible since 2011 when the FIT and the Small Renewable Energy Power Programme (SREP) was established. 30MW of biogas generation facilities was approved for the FIT by 2014. Biogas electricity plants are also eligible for a tax exemption on electricity sales for ten years through the Pioneer Status programme (MPOB, 2014).

Policy framework

GHG emissions reduction target	✓	**Energy efficiency target**	
Renewable energy target		**EE target for buildings**	
RE target for electricity	✓	**Building codes**	
Renewable energy support schemes	✓	**Appliances efficiency standards**	✓

Pakistan

Socioeconomic indicators

Population	188.92 m	**Population density**	245/km^2	**GDP / capita**	USD 1,429
HDI	0.53 (Low)	**Poverty headcount**	29.5 % (2013)	**Electricity access**	93.6 %

Greenhouse gas emissions (excluding LULUCF)

Total	320 M t CO_2e	**Per capita annual**	1.7 t CO_2e	**Emissions intensity of energy**	1.57 t CO_2/toe

Clean Development mechanism

Projects	90	**(of which CPAs)**	56	**Abatement potential**	4.8 M t CO_2e
Activities	Pakistan's portfolio of CDM projects largely stems out of the National CFL Project for energy efficiency in households and support sustainable lighting. Other projects support various renewable energy sources.				

Other market mechanisms and carbon pricing instruments

Pakistan's Ministry of Climate Change plans to set up local carbon markets under its Carbon Neutral Pakistan initiative to help reach its INDC target, but has had no major progress in implementing these up to date.

Climate change mitigation policy

In its INDC, Pakistan included only a statement of commitment to reduce its emissions after reaching peak levels, at an undefined date, subject to affordability, provision of international climate finance, transfer of technology and capacity building. Pakistan also stated that it would only be able to make specific commitments once reliable data on peak emission levels is available.
Pakistan's 2013 Climate Change Policy promotes a formal and legal binding climate strategy that includes various objectives from advancing research in environmental fields to heightening awareness of climate change. The Framework for Implementation of Climate Change Policy (2014-2030) was developed later that year to set out priority actions and schedules for target sectors.

Renewable energy support scheme

In 2009 the State Bank of Pakistan opened Scheme for Financing Renewable Projects providing loans at fixed rated for period of 10 years. Eligible projects must have capacity lower than 10 MW. Furthermore, in 2015 the National Electric Power Regulatory Authority (NEPRA) of Pakistan approved a net metering programme. The Economic Coordination Committee (ECC) of the Cabinet approved the "Framework for Power Cogeneration 2013 Bagasse and Biomass" as an addendum to the Renewable Energy Policy.

Policy framework

GHG emissions reduction target		**Energy efficiency target**	
Renewable energy target		**EE target for buildings**	
RE target for electricity		**Building codes**	
Renewable energy support schemes	✓	**Appliances efficiency standards**	

Mexico

Socioeconomic indicators

Population	127.01 m	**Population density**	65/km^2	**GDP / capita**	USD 9,009
HDI	0.75 (High)	**Poverty headcount**	53.2 % (2014)	**Electricity access**	99.1 %

Greenhouse gas emissions (excluding LULUCF)

Total	723 M t CO_2e	**Per capita annual**	5.9 t CO_2e	**Emissions intensity of energy**	2.36 t CO_2/toe

Clean Development mechanism

Projects	225	**(of which CPAs)**	33	**Abatement potential**	15.9 M t CO_2e

Activities Mexico has many different types of CDM project, but the dominant ones include landfill gas management, methane avoidance in manure, and lighting in households.

Other market mechanisms and carbon pricing instruments

Mexico introduced a carbon tax on fossil fuel sales and import by manufactures, producers, and importers that is in effect from 2014. This tax covers 40 % of the total GHG emissions. It is not a tax on the full carbon content of fuels, but on the additional emissions compared to natural gas. For the moment, natural gas is not subject to this carbon tax. A pilot voluntary ETS will begin in 2017, whilst Mexico has also signed a Joint Declaration of intent to pursue carbon market approaches with Quebec and Ontario (Climate Home, 2016). The PMR supports Mexico with the development of an MRV framework and accounting tools for credited NAMAs (PMR, 2016).

Climate change mitigation policy

Mexico's INDC includes the target to unconditionally reduce its emissions of greenhouse gases (GHGs) and black carbon by 25 % below baseline emissions in 2030. Mexico also proposed a 40 % reduction by 2030 conditional on certain requirements for the global agreement and international support. The Climate Action Tracker rates the ambitions of Mexico's INDC as "medium".
In April 2012, Mexico adopted the General Law on Climate Change, one of the world's first climate laws, and the first in a developing country. Under this law, Mexico aims to reduce its emissions by 50 % from 2000 levels by 2050.
In April 2014, the Ministry of the Environment and Natural Resources launched the Special Climate Change Program 2014-2018 (PECC). The PECC is a policy planning instrument derived from the General Law on Climate Change which includes specific sectoral targets and measures for the achievement of Mexico's climate objectives.

Renewable energy support scheme

Despite stating targets for renewable energy generation in the PECC, Mexico does not have any significant renewable energy support schemes.

Policy framework

GHG emissions reduction target	✓	**Energy efficiency target**	
Renewable energy target		**EE target for buildings**	
RE target for electricity	✓	**Building codes**	✓
Renewable energy support schemes		**Appliances efficiency standards**	✓

Brazil

Socioeconomic indicators

Population	207.84 m	**Population density**	25/km2	**GDP / capita**	USD 8,538
HDI	0.75 (High)	**Poverty headcount**	7.4 % (2014)	**Electricity access**	99.5 %

Greenhouse gas emissions (excluding LULUCF)

Total	1.012 G t CO_2e	**Per capita annual**	5.1 t CO_2e	**Emissions intensity of energy**	1.54 t CO_2/toe

Clean Development mechanism

Projects	352	**(of which CPAs)**	13	**Abatement potential**	44.8 M t CO_2e

Activities Brazil's CDM projects are mostly for renewable energy. Dominant are projects in hydro, wind, and biomass energy. Other major project types include methane avoidance and reforestation.

Other market mechanisms and carbon pricing instruments

As part of its activities under the PMR, the Brazilian government is considering the implementation of market instruments to meet Brazil's voluntary GHG reduction commitment and reduce overall mitigation costs. Brazil is currently assessing different carbon pricing instruments including an ETS and a carbon tax. The Ministry of Finance is developing design options and conducting comprehensive economic and regulatory impact assessments for both instruments (ICAP, 2016).

Climate change mitigation policy

Brazil's INDC includes a target to reduce net greenhouse gas emissions, including LULUCF, by 37% below 2005 levels by 2025. In addition, Brazil included an "indicative contribution" to reduce emissions by 43 % below 2005 levels (incl. LULUCF) by 2030. The Climate Action Tracker rates the ambitions of Brazil's INDC as "medium".

Renewable energy support scheme

In 2012, Resolution 482 of the Brazilian Energy Agency (ANEEL) entered into force introducing net metering policy in Brazil for small scale renewable generators. Renewable generators up to 1 MW capacity interconnected to low and medium-voltage grid are allowed to sell a surplus of the electricity back to the national grid in return for the electricity billing credit to be recuperated within 36 months.

Policy framework

GHG emissions reduction target	✓	**Energy efficiency target**	✓
Renewable energy target	✓	**EE target for buildings**	
RE target for electricity	✓	**Building codes**	✓
Renewable energy support schemes	✓	**Appliances efficiency standards**	

Kenya

Socioeconomic indicators					
Population	46.05 m	**Population density**	81/km2	**GDP / capita**	USD 1,376
HDI	0.54 (Low)	**Poverty headcount**	45.9 % (2005)	**Electricity access**	23 %
Greenhouse gas emissions (excluding LULUCF)					
Total	59 M t CO_2e	**Per capita annual**	1.3 t CO_2e	**Emissions intensity of energy**	0.54 t CO_2/toe
Clean Development mechanism					
Projects	47	**(of which CPAs)**	27	**Abatement potential**	15.5 M t CO_2e
Activities	Kenya's CDM projects mostly relate to energy efficiency in households through the improvement of cooking stoves. There are a handful of other projects for the development of renewable energy systems.				

Other market mechanisms and carbon pricing instruments

Kenya is one of 11 countries that has signed a bilateral agreement with the Japanese government for the Joint Crediting Mechanism (JCM). The Japanese government intends to allow JCM credits as offsets from fiscal year 2014 onwards and is currently working on setting up the necessary infrastructure.

Climate change mitigation policy

Kenya's INDC includes a target to reduce 30 % of GHG emissions by 2030, compared to BAU, under the condition that developed countries lend support in form of finance, investment, technology development and transfer, and capacity building.
Kenya's National Climate Change Response Strategy of 2012 is a non-binding climate strategy, completed by the National Climate Change Action Plan 2013-2017. The strategy's primary focus is to ensure that adaptation measures are integrated in all government's planning, budgeting, and development objectives. A Climate Change Bill was approved in 2012, but is currently still being amended through parliament debates.

Renewable energy support scheme

Kenya's REFIT was implemented in 2008 by the Ministry of Energy after a four-year process. The Kenyan government used to favour state-led investments in large-scale projects, foremost implemented by KenGen. While investors initially welcomed the REFIT policy, it was soon criticised as favouring state institutions. In response to the concerns, the policy was reviewed by the "FIT steering committee" and included biogas, geothermal, and solar PV as eligible technologies (Nganga & al., 2013).

Kenya's tariffs are not fixed but negotiated for each project. Kenya Power negotiates according to the actual costs for the project development and the rate of return for investors.

GHG emissions reduction target	✓	**Energy efficiency target**	
Renewable energy target		**EE target for buildings**	
RE target for electricity	✓	**Building codes**	
Renewable energy support schemes	✓	**Appliances efficiency standards**	

5 Methane Avoidance – Assessment of Project Discontinuation Risk

5.1 Overview of Subtypes and Identification of Groupings for Analysis

Following an initial review of the UNEP DTU project type classifications, several major and distinct project groupings were identified under the methane avoidance project type (see *Annex I-Subtype categorisations* for further details). The three major project groupings, which are analysed in this chapter, are the following:

- **Commercial livestock manure management (including methodologies AMS-III.D. & ACM10/AM6/AM16)**
  This category includes projects that recover methane by treating manure in anaerobic digesters and then flare the methane and/or utilise the resulting biogas for energy generation. For these projects, two major methodologies are used frequently (AMS-III.D and ACM10 which replaced AM6 and AM16); the main difference between the two is based on their application to small or large scale projects. These different methodologies are grouped for the analysis. A further potential split of the manure management subtype could be based on whether or not the project utilises recovered methane for energy generation; however, it is not clear from UNEP DTU information or project design documents to which projects these conditions apply, since many projects use methodologies that allow for energy generation although they may not yet actually do so, whilst other projects may generate electricity alongside the project despite not having a secondary methodology to reflect this. The potential differences between these conditions are reflected in the analysis of the projects.
- **Wastewater (including palm oil and others) (including methodologies AMS-III.H. & ACM14/AM13/AM22)**
  This category includes projects that recover methane by treating wastewater in anaerobic digesters and then flare the methane and/or utilise the resulting biogas for energy generation. Like for manure management, two major methodologies for small and large-scale projects are grouped for the analysis (AMS-III.H. and ACM14 which replaces AM13 and AM22). Differentiation of projects according to whether or not they utilise recovered methane for energy generation is relevant, but it is not possible to categorise projects in this way, based on screening of methodologies or PDD details, since many flaring projects included provisions in PDDs for potential upgrades to biogas utilisation. This subtype includes wastewater from various industries, including but not limited to palm oil mill effluent, starch, paper, rubber and various foodstuffs. An analysis of these projects is considered collectively.
- **Palm oil solid waste composting (AMS-III.F.)**
  This category includes projects that avoid methane emissions through the composting of solid wastes from the palm oil industry. A single distinct methodology accounts for all of the projects within this type.

The specific explanations for the derivation of these project groupings compared to the UNEP DTU CDM pipeline classification are presented in *Annex I-Subtype categorisations*.

These groupings are presented in Table 7, along with the number of projects in each of the eight pooled countries.

Table 6: Overview of the methane avoidance project type

Country	Commercial livestock manure management AMS-III.D. & ACM10/AM6/AM16	Wastewater (palm oil and others) AMS-III.H. & ACM14/AM13/AM22	Palm oil solid waste composting AMS-III.F.
India	2	**11**	0
Thailand	**8**	**67**	0
Malaysia	0	**56**	**33**
Pakistan	0	0	0
Mexico	**99**	2	0
Brazil	**59**	1	0

Country	Commercial livestock manure management AMS-III.D. & ACM10/AM6/AM16	Wastewater (palm oil and others) AMS-III.H. & ACM14/AM13/AM22	Palm oil solid waste composting AMS-III.F.
South Africa	3	0	0
Kenya	0	0	0

From the information in Table 7, the following countries appear to be the most interesting for analysis for the identified project groups, owing to the higher number of CDM projects:

(4) *Commercial livestock manure management projects with methodologies* AMS-III.D. & ACM10/AM6/AM16, with a focus on Mexico, Brazil and Thailand.

(5) *Wastewater with methodologies* AMS-III.H. & ACM14/AM13/AM22, with a focus on India, Thailand and Malaysia.

(6) *Palm oil solid waste composting* with the methodology AMS-III.F., applicable only to Malaysia.

5.2 Commercial Livestock Manure Management

5.2.1 Description of Project Type and Methodology

For the purpose of this analysis, *commercial livestock manure management* projects are those classified as *Manure* by the UNEP DTU pipeline, with methodologies AMS-III.D. – Methane recovery and flaring or utilisation in animal manure management (small scale) – and ACM10/AM16/AM6 – Destruction of methane emissions and displacement of a more-GHG-intensive service (large scale, AM6 and AM16 were superseded by ACM10). In general terms, the two methodologies refer to the same type of activities, with the small and large scale of the projects being the major difference. These projects are therefore analysed collectively, with due attention to potential differences between the two methodologies, where appropriate.

From the countries selected for analysis in this research undertaking, manure management projects are particularly prominent in Mexico and Brazil. Thailand hosts a fair number of these projects, whilst South Africa and India also host a very small number. Outside of the selected countries, manure management projects are also particularly relevant in the Philippines and China. In total, manure management projects are found in 19 countries, covering all global regions.

The technology employed is very similar for all projects in the *commercial livestock manure management* grouping, including for large-scale and small-scale operations. The technology and abatement methodology is summarised below. The term project discontinuation is used to generalise the conditions that would occur in the event that the mitigation activity is stopped.

Plausible project continuation and discontinuation scenarios are summarized in Table 7.

Table 7: Plausible continuation and discontinuation scenarios for commercial livestock manure management projects

Project summary	***Management of manure produced by commercially reared livestock, resulting in production of biogas, with flaring and/or utilisation.***
Process description of CDM project activity	Manure from the livestock is collected and treated in covered in-ground anaerobic digesters. These digesters are essentially lagoons which are covered by a high performance membrane, creating a high pressure cell with a gas seal. Instead of releasing uncontrolled methane emissions upon decay, the digesters capture the methane as biogas; effluent remains in the air tight cell for a period of time, where the closed system is controlled for optimum biogas production conditions, and to ensure that the methane emission potential of the remaining effluent and sludge is brought to a minimum. The biogas is extracted from the cells and combusted either in flares or used as a fuel for electricity production, for on-farm energy use or to feed into the grid. In the case of utilisation of the biogas for electricity generation, this may also incur additional emission reductions through the displacement of traditional sources of energy. The remaining sludge is usually used as bio-fertiliser, replacing artificial fertilizers and thus potentially reducing further emissions from the production and use of artificial fertilizers, whilst the remaining effluent water is either used for irrigation, recycled in a secondary lagoon and re-used on the farms, or evaporated in a secondary lagoon.

Mitigation project continuation scenario C1	The CDM project mitigation activity continues with utilisation of the biogas primarily for on-site electricity and steam generation.
Mitigation project continuation scenario C2	The CDM project mitigation activity continues with utilisation of the biogas for on-site energy and grid connected electricity generation.
Mitigation project continuation scenario C3	The CDM project mitigation activity continues and the captured biogas is primarily flared.
Project discontinuation scenario D1	Manure and effluent is routinely removed from livestock confinement facility and applied to cropland or pasture, or disposed into waterways or on land, within 24 hours of excretion.
Project discontinuation scenario D2	Manure is collected from livestock confinement facility and continues to be disposed in the existing lagoons, but the covering membranes are removed or trapped gas is released. The manure decays, causing emission of methane, while the remaining sludge is applied to the land.

Source: Authors' elaboration based on interviews and analysis of project design ocuments.

Figure 6 presents a brief overview of the processes and technologies typically involved in the plausible continuation and discontinuation scenarios for commercial livestock manure management projects, along with a comparison to the processes of potential project discontinuation scenarios. An analysis of the conditions and feasibility of these scenarios follows in the subsequent sections.

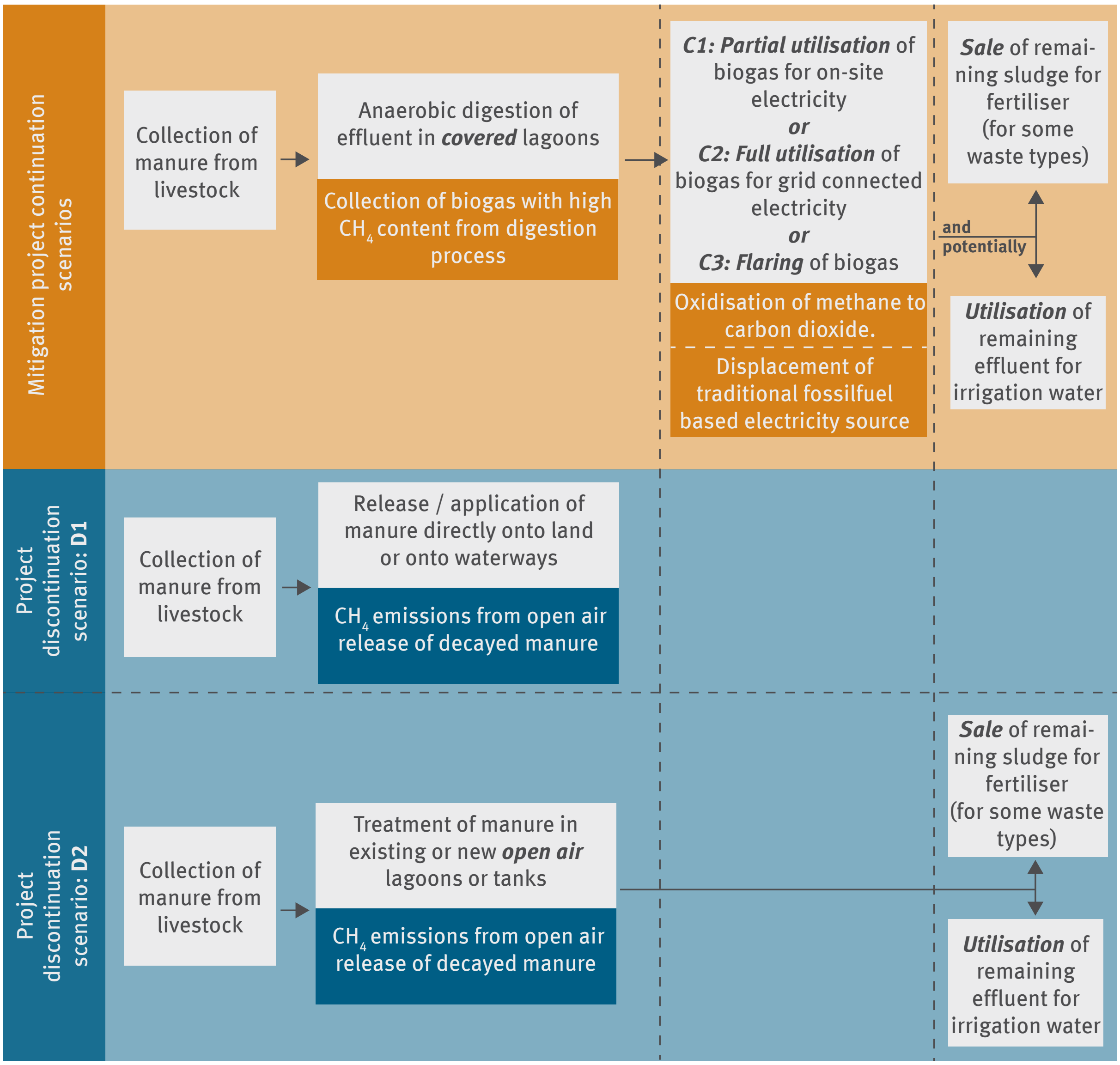


Figure 5: Overview of processes for plausible commercial manure management project scenarios

5.2.2 Current Status of Projects

In research by Warnecke et al (2015), 53 projects[6] for commercial livestock manure management in Thailand, Malaysia and India were randomly selected for evaluation. From these 53 projects, information was obtained for 35, including 30 projects in Mexico, 3 projects in Brazil and 2 projects in Thailand. The results indicated considerable difficulties with manure management projects in Mexico where just 5 % of the sampled projects were operational at the time of the evaluation in 2014, with the remaining projects having been abandoned, mostly due to the insolvency of the third party project operator (see Box 1). Information received from local stakeholders indicated a similar, albeit not so drastic, situation for Brazil. Further details on the specific situation for project abandonment in Mexico and Brazil are given in Box 1.

The problems affecting these abandoned projects were understood not to affect projects in Thailand, and both of the projects evaluated in Thailand reported continued regular operation.

Box 1: AgCert and manure management projects

AgCert International Limited, registered in Ireland, was created to develop animal waste management system projects for the generation and sale of CERs in the CDM. The company invested in mitigation equipment for hundreds of rural farms in Latin America, particularly in Brazil and Mexico. The land owners at the actual site of project implementation were not required to make any investment in the technologies and AgCert maintained responsibility for the investment and regular operation of the mitigation equipment, as well as monitoring and the verification and issuance of CERs. CERs and the profit generated from them accrued to AgCert, whilst the local farmers were allowed to keep the biogas that was produced by the activities. However, the company began to experience technical difficulties with its projects, as well as financial difficulties, and was sold to AES in 2008. After the international market price for CERs plummeted, AgCert officially entered into administration in June 2012, leaving its entire network of mitigation infrastructure in the hands and ownership of the local farmers, who had been taught very little about its practical use.

Most of these project activities abandoned the use of mitigation equipment immediately (93 % of methane avoidance projects in Mexico are dismantled, compared to a global average of 2 % excluding Mexico), although some larger farms continued to mitigate due to the benefits of using the biogas in other applications.

Source: Warnecke, Day & Klein (2015, p. 46)

5.2.3 Overview of Policy Landscape

Conditions for the continuation of manure management projects in the absence of CER revenues may be heavily influenced by local policy.

The most influential type of legislation, in this regard, would be legislation that refers to the continuation of the activity explicitly:

- Such regulation might entail obligatory standards for industry practices that stipulate the use of bio-digesters in manure management, or it may forbid certain undesirable practices without specifying which other technologies should be used instead. Technology or industry practice standards could be subjected either to livestock producers, or to sourcing and distribution companies, who in turn would enforce their requirements at the source of the chain.
- Voluntary standards are also important. In many countries, industry stakeholders understand that voluntary standards are often used to phase in legislative measures for which compliance will become obligatory in the future. The existence of voluntary standards for the use of bio-digesters is a signal of future policy for manure management, and stakeholders may be reluctant to cease the use of bio-digesters if they expect to be required to use them again in the near future, due to the costs of dismantling and re-implementing the use of the measures.

6 The selection of 53 projects was the outcome of an algorithm to ensure a minimum confidence level for the project type and country combinations analysed in that study (see Warnecke, Day, & Klein, 2015 Ch 2.4)

Other influential policies would be those that require certain practices for other components of the activity chain, such as regulations requiring the storage and or treatment of manure and effluent before potential discharge or land application. Relevant policy incentives are listed in Table 8 and considered for the financial assessment in the next section.

In addition to obligatory and voluntary industry standards, there are a wide range of policy measures that could *incentivise* the continuation of the activity, such as subsidies or tax incentives, renewable energy support schemes and grid connectivity regulations, amongst others.

An assessment of policies and measures in 34 developing countries found that legislation does often not support advanced livestock manure management practices sufficiently for such practices to become widespread (Teenstra et al., 2014). Of the 34 countries analysed by Teenstra et al., 30 were found to have policies related to manure management. These policies were mostly related to storage, treatment and application of manure, although approximately half of the countries assessed also had policies specifically related to manure digestion, in particular through regulations related to air emissions from farms. These results are in line with a parallel assessment conducted by the Global Methane Institute (GMI, 2014). However, even in countries where policies existed, policy frameworks were usually found to be insufficient due to weak levels of enforcement, as well as a lack of coherence including direct contradiction between policies administered by different ministries, which include the ministries for agriculture, environment, energy and public health (Teenstra et al., 2014).

Table 8: Regulations for manure management in Mexico, Brazil and Thailand

<table>
<tr><th></th><th>Mexico
(99 projects)</th><th>Brazil
(59 projects)</th><th>Thailand
(8 projects)</th></tr>
<tr><td rowspan="2">**Regulations for biogas capture and GHG emissions**</td><td>×</td><td>×</td><td>×</td></tr>
<tr><td colspan="3">No direct standards or regulations for GHG emissions</td></tr>
<tr><td>**Regulations for manure application/discharge**</td><td>✓
The General Act of Prevention and Comprehensive Waste Management requires facilities to submit waste management plans. The *Mexican Official Standard 001* sets limits on the properties of discharge, requiring treatment for compliance (SEMARNAT, 2008). The National Emission Registry requires facilities with emissions over a certain threshold to prepare emission reduction plans.</td><td>✓
Environmental standards forbid the discharge of untreated effluent. Legislation also exists to control the application of manure as fertiliser, but policies from the ministries for agriculture and environment are in places incoherent (Teenstra et al., 2014).</td><td>✓
The Ministerial Notification on Livestock Farm Standards (1999) requires manure and wastewater to be disposed of in a way that ensures no spilling and limits local environmental damage.</td></tr>
<tr><td>**Incentives for anaerobic digestion**</td><td colspan="2">~
The incentive policy landscape in Mexico and Brazil is very similar.
Grid connections are possible for net metering although administrative processes are prone to delays, and complicated to the extent that connections are not feasible for small scale operators with limited capacities in this area. No sale of electricity to the grid is possible, except for under specific programmes for which manure management projects are not eligible.</td><td>✓
Grid connection for biomass, biogas and other renewable energy projects has been possible under purchase power agreements (PPA) since 2007, with adder rates paid in addition to the wholesale electricity price for 7 years.</td></tr>
</table>

Table 8 shows that Mexico, Brazil and Thailand all have regulations in place that require some rudimentary treatment of the manure. The impact of these regulations in all three countries is not guaranteed: Teenstra et al. (2014) assess that policy coherence is marred by some contradictions and gaps, and that enforcement is generally carried out but not particularly strict. However, it is considered that operators will comply with the regulations in the majority of cases.

In Mexico, legislation also exists that requires larger livestock operations with very high emissions to develop plans to reduce emissions. Whilst this regulation does not require any specific action it is considered a factor that will make larger farms more likely to pursue emission reduction activities since they are better informed, and might also interpret the legislation as a warning for more specific regulations to come in the future.

The implications of regulations for the plausible scenarios is summarised in Table 9. Scenario D1: *Direct discharge or land application*, is not compatible with regulations in any of the three countries analysed, as it would exceed the thresholds for discharge regulations in all countries unless previously treated. This scenario is excluded from the further analysis.

Table 9: Compatibility of manure management scenarios with regulations in Mexico, Brazil and India

Scenario	Compatibility of scenarios with regulations		
	Mexico	Brazil	Thailand
C1: Anaerobic treatment with grid connected electricity	✓	✓	✓
C2: Anaerobic treatment with on-site energy	✓	✓	✓
C3: Anaerobic treatment with flaring	✓	✓	✓
D1: Direct discharge or land application	× Regulations in all 3 countries require manure to be treated before discharge	×	×
D2: Anaerobic treatment and biogas release	✓	✓	✓

5.2.4 Assessment of costs, financial benefits and barriers

In addition to direct primary research through interviews with in-country stakeholders, a selection of projects were analysed with regards to the anticipated financial conditions of the project activities, according to the information included in, or attached to, their PDDs.

In this subsection, the costs and benefits of each of the scenarios are analysed, along with other financial and non-financial barriers for the pursuance of the scenario. Costs are considered in terms of ongoing operating expenditures and maintenance for certain processes, including expenditures for labour, additional energy demand, regular purchases of process inputs, repair and replacement of parts, where necessary.

The financial benefits of biogas capture can also be significant. Biogas captured can be fed into generators for on-site or grid connected electricity, saving costs for the procurement of other fuels, or for the purchase of electricity from the grid, and generating revenues for electricity sales. Projects are also able to use the treated or non-treated manure as fertiliser, saving costs on inorganic fertilisers, or generating revenues from fertiliser sales.

Table 10: Potential costs and financial benefits for commercial manure management project scenarios

Scenario	Operation and maintenance costs				Benefits		
	Digesters	Flaring equipment	Energy generation equipment	Grid connection equipment	Sale of electricity	Electricity cost savings	Fertiliser from digested effluent
C1: Anaerobic treatment with on-site energy	✓	✓	✓			✓	✓
C2: Anaerobic treatment with grid connected electricity	✓	✓	✓	✓	✓	✓	✓
C3: Anaerobic treatment with flaring	✓	✓					✓
D1: Direct discharge	n.a. (not compliant with regulations – see 5.3.2)						
D2: Anaerobic treatment and biogas release	✓						✓

Source: Authors' elaboration based on PDD analysis, interviews and literature

Table 10 gives an overview of the types of costs and benefits incurred by wastewater projects, under the scenarios identified. Closer analysis of these costs and benefits, along with potential barriers, is given for each scenario below the table.

Project continuation scenario C1: Anaerobic treatment with on-site electricity

For projects that included utilisation of the biogas in their initial project designs, the biogas was used in all cases for electricity generation only, rather than for heat. Regular expenditure is incurred, additional to the expenditure from flaring projects, for maintenance of biogas management systems, and generators. In most cases, the technology used are relatively small motors; only in the largest projects, where more sophisticated motors are used, are there significant expenses for electrical transformation equipment and machine rooms.

For projects with biogas utilisation, financial benefits may be incurred through saving electricity costs in the case of utilisation for on-site electricity.

According to the information in the investment analysis spreadsheets attached to the PDDs of a selection of projects in Mexico, Brazil and Thailand, the financial revenues from electricity savings for on-site usage would be significant, accounting for between approximately 10 % and 30 % of the initial investment costs, per year, compared to operation and maintenance costs of between approximately 5 % and 15 % of the initial investment costs. The actual volume of cost savings, between the range of 10 % and 30 %, depends largely on the proportion of biogas that is utilised; projects with higher rates of utilisation incurred larger rates of cost savings compared to projects where only small amounts of the biogas was utilised whilst the remainder was flared. While the actual difference between the financial revenues and operational costs vary for each project, the financial revenues comfortably exceeded the operational costs in each one of the projects analysed.

As such, the evidence indicates that the additional financial benefits of using biogas for electricity on-site would far exceed the additional operating expenditures for these projects. This theoretical assessment is based on information in PDDs which assumed a grid electricity price, on average, of 0.09 USD/kWh in Mexico, 0.07 USD/kWh in Brazil, and 0.07 USD/kWh in Thailand. Information from the investment analysis documents indicates that the financial benefits of on-site usage would continue to exceed the operating expenditures as long as grid electricity prices remain higher than, on average, 0.07 USD/kWh in Mexico, 0.04 USD/kWh in Brazil, and 0.03 USD/kWh in Thailand. Average retail electricity prices in 2015 were 0.12 USD/kWh in Mexico (Climatescope, 2015b), 0.12 USD/kWh in Brazil (Climatescope, 2015a), and approximately 0.08 USD/kWh in Thailand (Thailand Board of Investment, 2015).

Table 11: Operating costs and financial benefits for manure management projects

Annual finance flows	Projects with biogas utilisation		
	Mexico	Brazil	Thailand
Financial benefits as % of operating expenditures	150 %	170 %	250 %
Net balance of continued operation	Major net gains		

Finance flow data is based on the authors' calculations from analysis of a random selection of 15 PDD Investment Analyses. Figures given are averages from the analysed PDD documents. Data is approximate due to the small sample size, but the significance of the trends is clear.

Table 11 gives a summary of the theoretical financial conditions for manure management projects with utilisation, excluding CER revenues, following completion of the initial capital expenditure. The conditions are theoretical, since they are based on the ex-ante expectations of the project developers, from the finance plans reported in PDDs. In the summary table, the regular expenditure for repair or replacement of electricity generation equipment are included in the operating expenditures. For all countries studied, the net financial benefits from electricity savings appear to be far superior to the operating expenditures for biogas utilization projects.

Despite the general positive financial implications for these projects, there are major barriers for many of these projects in Brazil and Mexico, due to differences between project ownership and the division of benefits. There are two major project ownership models for livestock manure management projects: either the owner of the CDM project is also the owner or a direct or indirect stakeholder of the farm or farm operations, or the owner of the project is a third party organisation which invests in the implementation of projects on one or multiple farms in which it has otherwise no stake.

In the case that manure management CDM projects are owned and operated by the farm owners or stakeholders, there is usually no conflict in the division of benefits and the ownership structure poses no positive or negative impact on the risk of project discontinuation.

In the case that manure management CDM projects are owned by third party organisations, project conditions are more complicated. Previous analysis of this project type in Mexico and Brazil has shown that third party ownership for manure management projects usually entails that the third party owner is also the owner and ongoing operator of the physical mitigation equipment (Warnecke, Day, & Klein, 2015). In the case of manure management projects, the potential financial benefits analysed in the previous section accrue as energy cost savings to the farm site managers directly; the third party project owners mainly benefitted from CER revenues but did usually not benefit from cost savings due to electricity generation. If the third party ceases to exist, the plant operators would accrue financial benefits from taking over and utilizing the biogas for energy generation. In practice, however, barriers can impede continued operation and rather lead to a closure of operation. The impact that this scenario would have on the continuation of the mitigation activity depends upon the extent to which the local farmers are able to continue using the bio-digesters and generators.

Box 1 in section 5.2.2 explains that a major proportion of manure management projects in Mexico and Brazil are known to have been already dismantled, since farmers lacked the technical capacity and resources to continue with the maintenance and operation of the equipment once the project owner was absent. This condition is understood to have affected at least 88 % of manure management projects in Mexico and at least 58 % of manure management projects in Brazil[7]. Of the remaining projects in Mexico and Brazil, analysis of PDDs shows that all other projects, except for two projects in Mexico and a maximum of five projects in Brazil, were operated under the same ownership structure and are likely to have had the same fate.

The situation facing these projects in Brazil and Mexico is understood to be dependent, in both countries, on the size of the individual farms and the technology used[8]:

7 These are the proportions of projects that were administered and operated by AgCert or Ecosecurities, according to project design documents. Warnecke, Day & Klein (2015) find that 100 % of sampled manure management projects administered by AgCert or Ecosecurities in Mexico and Brazil have been dismantled.

8 The conditions facing small and large projects in Brazil and Mexico were determined through interviews with the director of BRASCARBON in Brazil and the biogas research director of the University of Coahuila in Mexico.

Smaller farms (e.g. less than 600 standing animals)

The large majority of farms where projects have installed mitigation technologies are relatively small. These farms are understood to be generally interested in the use of technologies, but face several barriers that are understood to be insurmountable in the current situation:

- Farm operators do not have the skills and knowledge to operate and maintain the bio-digesters or electricity generators left in their possession after the departure of the third party who was previously operating the equipment.
- Generators used by these projects are small basic motors, which usually require complete replacement at regular intervals, rather than the replacement of just corroded parts of a system. This entails costs that are proportionally comparable to initial capital expenditures. Most farms cannot afford the costs, whilst others who may be in a position to do so may still not due to a high risk perception for an asset not connected to the main business activity.

Larger farms (e.g. over 600 standing animals)

Larger farms face some of the same problems as smaller farms, but are considered more likely to overcome the barriers for the following reasons:

- Larger farms are more likely to have, or to have access to, trained personnel and more turnover to invest in the acquisition of knowledge and capacity for use of equipment.
- Larger farms are more likely to use more sophisticated imported motors, which are prohibitively expensive for small operations, which are more resistant to corrosion, and which require only partial renewed capital investments for replacements of parts, rather than replacement of the complete system.

Projects in Thailand are generally large farms and are not known to be affected by this issue.

Project continuation scenario C2: Anaerobic treatment with grid connected energy

In Mexico, Brazil and Thailand, conditions were not conducive to grid connections for projects at the point of project design, so information on the prospects for grid connected projects was not available from PDDs. However, evidence indicates that many projects that generate electricity for on-site usage may also be able to utilise a greater proportion of the produced biogas than they accounted for in their initial project designs, due to the recent introduction of conducive laws for electricity feed-in tariffs for renewable energies, including biogas; this change in condition increases the net benefit of the activity further than the benefit analysed in scenario C1.

In Thailand, grid connections are theoretically possible under a FIT scheme with revenues for electricity sales, however the scale of operations and the complications involved in grid connections mean that grid connected manure management projects remain a rare exception. In Mexico and Brazil, excess electricity fed into the grid can be claimed against electricity bills in times when the project is not generating electricity, but revenues cannot be generated.

Projects in Mexico and Brazil are affected for this scenario by the same barriers as those identified in the analysis of scenario C1.

Project continuation scenario C3: Anaerobic treatment with capture and flaring of biogas

For projects that only flare gas without utilisation, expenditure is incurred for personnel to supervise the use of the bio-digesters and for regular maintenance of the manure collection system, the bio-digester equipment, biogas filters and piping. Annual costs for operation and maintenance of flaring only projects were estimated in most PDDs to account for somewhere between 6 % and 16 % of the initial investment cost[9]. The investment analyses attached to PDDs of these projects do not account for any additional financial benefits, aside from CER sales.

9 Authors' calculations based on analysis of a selection of 15 PDD Investment Analyses. The remaining information from PDDs in this section is taken from analysis of the same collection of projects.

Technically, financial benefits may occur in the case of ongoing subsidy payments or tax incentives, from revenues of bio-fertilisers, or from the receipt of tipping fees if co-digesting manure with waste from third parties, but these potential sources of revenues do not appear to play a role for CDM projects in Mexico, Brazil or Thailand, due to limited waste management networks and also the basic digestion technologies applied, which do not support such co-digestion practices efficiently. As such, the financial benefits for continued operation of the project activity for flaring projects are considered to be negative. This situation applies for all of the countries examined. Furthermore, projects in Mexico and Brazil are affected for this scenario by the same barriers as those identified in the analysis of scenario C1.

Project discontinuation scenario D2: Anaerobic treatment of manure with biogas release

Financial conditions for the discontinuation scenario are understood to be neutral, or slightly positive due to the revenues from fertiliser, if it is considered that the marginal costs for the operation of the treatment equipment are zero since these steps are compulsory, due to the regulations observed in the previous section. If this component is discounted, on the basis that the same benefit exists for all scenarios then the financial situation is neutral.

5.2.5 Summary of vulnerability and scenarios for manure management projects

Table 12 gives a summary for the potential scenarios for manure management projects in order of their financial attractiveness regarding the ongoing costs and benefits. The information in financial conditions relates only to ongoing financial flows and does not include upfront capital expenditures. Compatibility with regulations and other barriers are included in the table to help identify the most likely scenario for continuation.

Table 12 shows that project continuation scenarios with utilisation of biogas for grid connected electricity or for on-site electricity would be more attractive than the discontinuation scenarios. The continuation of mitigation activity with capture and flaring of the biogas is clearly less attractive than either discontinuation scenarios.

Although Table 12 shows the continuation scenarios to be most economically attractive, these scenarios are considered unlikely in Brazil and Mexico due to the major barriers, which are reported to be insurmountable on most of the farms where CDM projects were originally installed.

As such, the most likely scenario for these projects is discontinuation scenario D2: *Anaerobic treatment of wastewater with biogas release*. Commercial livestock manure management projects in Mexico and Brazil and therefore deemed to be at high risk: indeed, the very large majority of these projects are known to have already dismantled.

Projects in Thailand are not usually affected by the barriers faced in Brazil or Mexico – these are usually larger farms with the project activity operated by the farm owners rather than third party entities –, so these projects are likely to proceed with continuation scenario C1: *Anaerobic treatment with on-site energy*. This scenario is reported to be common practice in Thailand even on farms that are not registered as CDM projects.

Table 12: Summary of scenarios for manure management projects

Scenario	Compatible with regulations			Financial conditions	Barriers in analysed countries
	Mexico	Brazil	Thailand		
C2: Anaerobic treatment with grid connected electricity	✓	✓	✓	Very positive	No major barriers in Thailand. Major barriers in Mexico and Brazil due to difficulties to establish grid connection.
C1: Anaerobic treatment with on-site energy	✓	✓	✓	Positive	No major barriers in Thailand. Major barriers in Mexico and Brazil due to departure of project operators and lack of capacity.

D2: Anaerobic treatment with biogas release	✓	✓	✓	Neutral	None
C3: Anaerobic treatment with biogas capture and flaring	✓	✓	✓	Negative	No barriers in Thailand. Major barriers in Mexico and Brazil due to departure of project operators and lack of capacity.
D1: Direct effluent discharge	×	×	×	-	-

5.3 Wastewater

5.3.1 Description of Project Type and Scenarios

For the purpose of this analysis, wastewater projects are those classified as *Palm oil wastewater* and *Other wastewater* by the UNEP DTU pipeline, with methodologies AMS-III.H. & ACM14/AM13/AM22. These methodologies refer to small scale and large scale versions of a similar project activity: anaerobic treatment of wastewater for methane recovery, with flaring or utilisation.

From the countries selected for analysis in this research undertaking, wastewater projects are particularly prominent in Thailand, Malaysia and India, where 67, 56 and 11 projects were successfully registered by January 2016, respectively. As such, conditions for projects in Thailand, Malaysia and India are considered within this analysis. In total, wastewater methane recovery projects are registered in 22 countries worldwide, with relatively large project collections in Indonesia, China and Vietnam.

Wastewater projects include a large range of industries: more than half of the projects treat wastewater from palm oil mills, but projects also exist that treat wastewater from other industries, including facilities that process starch, ethanol, paper, rubber and various foodstuffs, amongst others. The specific technology employed is variable according to the type of facility and other conditions, but all technologies apply a similar process, which is the anaerobic digestion of the wastewater for biogas production.

Plausible project continuation and discontinuation scenarios are summarized below.

Table 13: Plausible continuation and discontinuation scenarios for wastewater projects

Project summary	***Effluent wastewater from the industrial activities is treated anaerobically, thereby generating biogas which may be partially flared and partially utilised.***
Process description of CDM project activity	The specific situation of the mitigation scenario varies according to the industry and the technology used, but the overall concept is similar for all projects. Industrial wastewater is treated in an anaerobic facility that generates biogas. In the most basic applications, this involves the use of a membrane cover over existing or new open air lagoons, or a steel lid on existing or new open air tanks, whilst in other projects a range of more specialised technologies are used, including continuous flow stirred-tank reactors (CSTR), up-flow anaerobic sludge blankets (UASB) and internal circulation reactors (ICR). The captured biogas is either used as a direct replacement for other fuels in existing boilers for on-site steam generation or used for electricity generation, either for on-site energy use and/or for integration and sale to the national grid. Excess biogas that is not utilised is flared.
Mitigation project continuation scenario C1	The CDM project mitigation activity continues with utilisation of the biogas primarily for grid connected electricity generation, but also for on-site electricity demands.
Mitigation project continuation scenario C2	The CDM project mitigation activity continues with utilisation of the biogas primarily for on-site electricity and steam generation.
Mitigation project continuation scenario C3	The CDM project mitigation activity continues and the captured biogas is primarily flared.
Project discontinuation scenario D1	Effluent wastewater is discharged directly to land or waterways.

Project discontinuation scenario D2	Effluent wastewater still goes through a process of anaerobic treatment in order to reduce the chemical oxygen demand (COD) value of the wastewater, before the effluent is discharged or applied to land. During the treatment process, the wastewater is usually stored in pre-existing or newly constructed open air lagoons or tanks for a period of time, where it undergoes digestion with uncontrolled release of methane.
Project discontinuation scenario D3	Effluent wastewater goes through a process of aerobic treatment in order to reduce the chemical oxygen demand (COD) value of the wastewater, before the effluent is discharged or applied to land. An aerobic treatment system (ATS) typically requires more advanced technologies where aerobic bacteria is fed through the wastewater to digest the biological wastes. The quality of the treatment and the remaining effluent is typically greater than for effluent treated anaerobically; resulting biochemical oxygen demand (BOD) values are better than for anaerobic systems, whilst the effluent is also relatively odourless, compared to anaerobically digested effluent. An aerobic digestion scenario also results in the reduction of methane emissions.

Source: Authors' elaboration based on interviews and analysis of project design documents.

Figure 6 presents a brief overview of the processes and technologies typically involved in the plausible continuation and discontinuation scenarios for wastewater projects, along with a comparison to the processes of potential project discontinuation scenarios. An analysis of the conditions and feasibility of these scenarios follows in the subsequent sections.

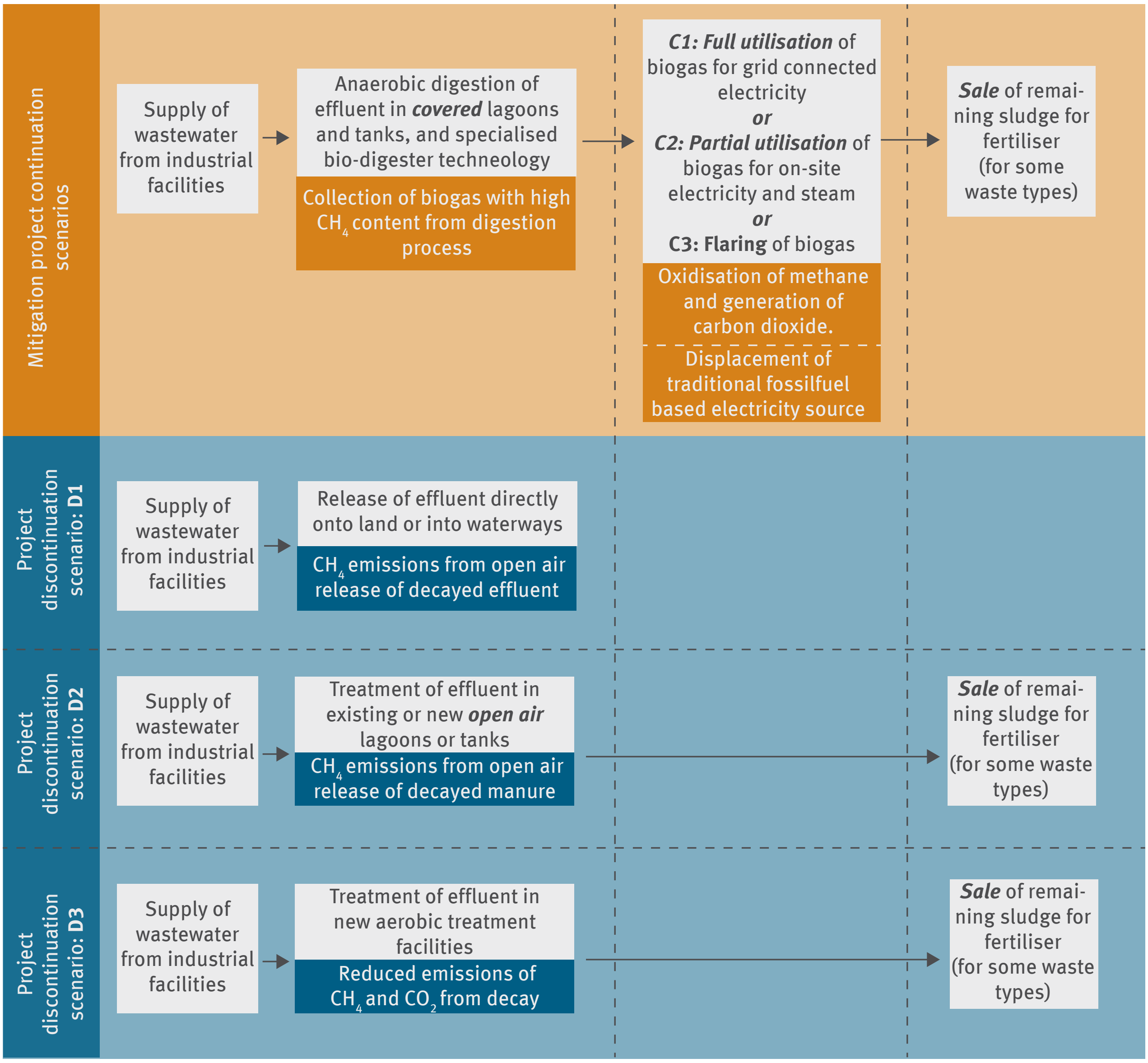


Figure 6: Overview of processes for plausible wastewater project scenarios

5.3.2 Current Status of projects

In research by Warnecke et al (2015), 52 projects[10] for wastewater methane recovery in Thailand, Malaysia and India were randomly selected for evaluation. From these 52 projects, information was obtained for 46, including 9 projects in India, 22 projects in Malaysia and 15 projects in Thailand. Across the 46 projects, approximately 90 % had been implemented, and 95 % of the implemented projects remained in regular operation at the time of the evaluation in 2014. All of the evaluated projects in Thailand and India were implemented and operational, while the rate of implementation in Malaysia was slightly lower, at 80 %.

For Thailand, all of the projects evaluated also indicated that they would remain operational for at least the following 12 months, whilst equivalent information for projects in Malaysia and India was not available.

5.3.3 Overview of policy landscape

The following types of policy instruments can influence the feasibility of waste water activities:

- **Standards and regulations for wastewater greenhouse gas emissions**
  Regulations may determine limits for greenhouse gas emissions from wastewater, or may prescribe and/or prohibit specific technologies and practices for wastewater treatment (UNEP, 2015). For example, such regulations may prohibit the release of methane from open air anaerobic digestion.
- **Standards and regulations for related wastewater discharge (indirect impact)**
  Most countries have standards that control the properties of effluent discharged from industrial facilities, thereby requiring industries to treat their wastewater to make it compliant with the national discharge standards. In addition to the standards, industrial facilities may be required to be licensed, and to proactively monitor and report on the properties of their discharge. Such regulations effectively require most industries to treat their wastewater through digestion before discharge or land application, requiring lagoons and or storage tanks for anaerobic treatment, or more sophisticated systems for aerobic treatment. Under these circumstances, the option to avoid the use of treatment facilities, would not be a possibility; as such, the initial components for anaerobic or aerobic digestion would usually be in place, even if there is no recovery of biogas produced.

In addition to obligatory and voluntary industry standards, there are a wide range of policy measures that could *incentivise* the continuation of the activity, such as subsidies or tax incentives, renewable energy support schemes and grid connectivity regulations, amongst others. Relevant policy incentives are listed in Table 14 and considered for the financial assessment in the next section.

Table 14: Regulations for wastewater management in Thailand, Malaysia and India

	Thailand (67 projects)	**Malaysia** (56 projects)	**India** (11 projects)
Regulations for wastewater GHG emissions	×	×	×
Regulations for wastewater discharge	✓ The Pollution Control Department established Industrial Effluent Standards in 1996, including a maximum COD value of 120 mg L^{-1} for all industries generally (GMI, 2010).	✓ 2009 Environmental Regulations for Industrial Effluents: standards prescribe maximum COD values for effluent, ranging from 80 mg L^{-1} to 400 mg L^{-1} according to the specific industry (DOE, 2010).	✓ Schedule VI of the 1986 Environmental Protection Rules determine a maximum COD value of 250 mg L-1 for effluent from all industries generally (Eldho, 2014).

10 The selection of 52 projects was the outcome of an algorithm to ensure a minimum confidence level for the project type and country combinations analysed in that study (see Warnecke, Day, & Klein, 2015 Ch 2.4)

Incentives for waste water treatment	✓ Grid connection for bio-mass, biogas and other renewable energy projects has been possible under purchase power agree-ments (PPA) since 2007, with adder rates paid in addition to the wholesale electricity price for 7 years.	✓ Grid connection for renewable energy pro-jects including biogas has been possible since 2011 when the FIT and the Small Renewable Energy Power Programme (SREP) was established. Biogas electricity plants are also eligible for a tax exemption on elec-tricity sales for ten years through the Pioneer Status programme (MPOB, 2014).	✓ A feed-in tariff was laun-ched in 2009 which covers biogas energy. Under the Biogas based Power Generation Program-me (BPGP), subsidies were provided to small-scale project operators to purcha-se equipment for these technologies (TERI, 2007).

Table 14 summarises the relevant policy environment for wastewater projects in Thailand, Malaysia and India. None of the countries has in place a policy that specifically requires the control of GHG emissions, and therefore the regular continuation of the project activity. However, all three of the countries require some level of waste-water treatment process to take place to comply with effluent discharge standards.

The implications of regulations for the plausible scenarios is summarised in Table 15. Scenario D1: Direct discharge of untreated effluent is not compatible with regulations in any of the three countries analysed and is excluded from the further analysis.

Table 15: Compatibility of wastewater management scenarios in Thailand, Malaysia and India

Scenario	Compatible with regulations		
	Mexico	Brazil	Thailand
C1: Anaerobic treatment with grid connected electricity	✓	✓	✓
C2: Anaerobic treatment with on-site energy	✓	✓	✓
C3: Anaerobic treatment with flaring	✓	✓	✓
D1: Direct discharge	×	×	×
	Regulations in all 3 countries require effluent to be treated before discharge		
D2: Anaerobic treatment and biogas release	✓	✓	✓
D3: Aerobic treatment	✓	✓	✓

5.3.4 Assessment of Costs, Financial Benefits and Barriers

In addition to information and insights from local experts, 26 projects from different countries and industries were selected for analysis of financial conditions, according to the information included in, or attached to, their PDDs. An analysis of the information obtained, regarding anticipated costs and revenues showed that the major differences occurred according to the mode of utilisation of the biogas. Significant differences between the financial conditions for different industries, or for different mitigation technologies, could not be detected.

The general costs and benefits applicable are similar to those for commercial livestock manure management projects. In addition to the general costs and benefits mentioned in the previous section, and although not included in the investment analyses of PDDs, some projects are also able to use the digested effluent as ferti-liser, saving costs on inorganic fertilisers, and also potentially increasing the crop yield due to the fertiliser’s high quality (Yeoh, 2004).

Table 16 gives an overview of the types of costs and benefits incurred by wastewater projects, under the scenarios identified. Closer analysis of these costs and benefits, along with potential barriers, is given for each scenario below the table.

Table 16: Potential costs and financial benefits for wastewater project scenarios

Scenario	Operation and maintenance costs				Benefits		
	Treatment equipment	Flaring equipment	Energy generation equipment	Grid connection equipment	Sale of electricity	Electricity cost savings	Fertiliser from digested effluent
C1: Anaerobic treatment with grid connected electricity	✓	✓	✓	✓	✓	✓	✓
C2: Anaerobic treatment with on-site energy	✓	✓	✓			✓	✓
C3: Anaerobic treatment with flaring	✓	✓					✓
D1: Direct discharge	n.a. (not compliant with regulations – see 5.3.2)						
D2: Anaerobic treatment in lagoon and biogas release	✓						✓
D3: Aerobic treatment	✓						✓

Source: Authors' elaboration based on PDD analysis, interviews and literature

Project continuation scenario C1: Anaerobic treatment with grid connected electricity

Projects with electricity generation and grid connectivity are able to obtain near to maximum potential from the biogas, since excess biogas that is not used on-site can be converted into additional revenues. Whether or not the project has to flare any of the biogas depends upon the capacity of the power generation facilities, compared to the regular flow of biogas.

In their ex-ante investment analyses, projects with plans for this model all forecast very favourable financial conditions, following the upfront capital investment, which is considerably higher than for projects without electricity generation and grid connection. This is because the operating costs for the production of the biogas do not change, whilst the proportion of the produced biogas that is utilised is higher. This, in effect, significantly reduces the operating costs per unit of utilised biogas. Furthermore, the value per unit of biogas in this application can also be greater: in some cases, the revenues obtained for electricity exported to the grid are greater than the retail prices paid for electricity on site, due to tariff additions linked to national programmes for the promotion of renewable energies. For example, projects with grid integration in Thailand receive a tariff addition for electricity revenues for the first seven years, through the Adder rates for Very Small Power Producer (VSPP) programme (see country profile in section 4).

Without exception, all of the analysed projects with grid integration forecast that financial benefits would far exceed ongoing operating expenditures and maintenance costs. Across these projects, annual revenues were equal, on average, to approximately 240 % of annual operating expenditures, with a range from 135 % to nearly 700 %.

Analysis of economic conditions for palm oil mill effluent wastewater projects by Yeoh (2004) supports the general conclusion that ongoing benefits for wastewater projects usually exceed costs. The study finds that the financial benefits of biogas utilisation in palm oil mill effluent wastewater treatment facilities in Malaysia, should be more than three times greater than the additional operating expenditures of the activity, assuming full utilisation of the produced biogas. This paper also finds that additional benefits from use of the treated waste as fertiliser, and subsequent yield improvements due to the bio-fertilisers high quality, are also highly significant, and may offset more than half of the operating expenditures alone.

Much has changed in the industries of Malaysia since the study was conducted in 2004, but local expert insights indicate that the trends from these findings remain very much relevant.

Although the benefits for these projects are higher than the operating and maintenance expenditures, it must be considered that a major component of these expenditures comes in the form of significant renewed investments for repairing or replacing parts of corroded motors at regular intervals. Whilst the indications show that such investments are financially attractive, availability of funds for large investments, as well as appetite for the risks involved, is not certain. However, unlike for commercial manure management projects, where some farming operations are particularly small, wastewater projects are normally operated by relatively large industrial entities who would be expected to be in a position to make these regular investments.

The potential of wastewater projects to continue under or move towards this scenario depends upon local policy and infrastructure for grid connectivity, as well as the upfront cost of the equipment. The information compiled in section 4 on renewable energy support schemes indicates that conducive policies for grid connectivity have been passed in Thailand, Malaysia and India in recent years.

In Thailand, all industrial facilities, in theory have the potential to connect and sell energy to the grid, although there are some delays in processing applications for grid connectivity. It is speculated that these delays affect approximately 20 %-30 % of industrial facilities[11].

The costs of new equipment for projects is greatest for projects that began their CDM project with flaring only, since the acquisition of generating equipment and grid connectivity equipment would be required. In the case of wastewater projects, this is not a relevant consideration, since there are no known projects that began with a flaring only model. In any case, it is generally understood that this would not be an insurmountable barrier for any project currently, even in the theoretical example that a project started with only flaring equipment, since the size of the facilities and the scale of the benefit is large enough to make the investments feasible. In support of this conclusion, electricity generation is now the standard industry practice for industrial facilities producing wastewater in Thailand, Malaysia and India, with hundreds of facilities adopting this technology without a CDM registration.

Project continuation scenario C2: Anaerobic treatment with on-site energy

Conditions for these projects depend upon the energy requirements of the facility. For facilities where there is a high energy demand, the proportion of biogas which may be utilised for financial benefit is also higher. This demand is limited in some facilities due to the high availability of other biomasses, such as solid wastes in the case of palm oil mills. Projects with electricity generation are able to utilise a greater proportion of the biogas for greater cost savings. In the case that the possibility does not exist to export excess electricity to the grid, the remaining biogas is flared and its economic potential is lost. The ex-ante investment analyses of these projects do not provide any conclusive trends. Across the analysed projects, expected annual cost savings were equal, on average, to approximately 170 % of ongoing costs, although some projects had forecasted costs in excess of savings. This variability is most likely based on the availability of alternative fuel (e.g. biomass) and therefore the proportion of biogas that can be utilised.

A factor that reduces the attractiveness of this scenario in Thailand specifically, is that in the current situation, the potential financial savings from use of biogas for on-site energy is low due to the very high availability of biomass, which is used in most cases to provide all of the on-site energy demands.

Project continuation scenario C3: Anaerobic treatment with capture and flaring of biogas

No examples could be found of wastewater projects without utilisation of any of the biogas. In theory, based on the evidence of other projects, projects with no utilisation would accrue no benefits to cover their continuation costs. Revenues or cost savings from fertiliser production are considered insignificant compared to the costs incurred.

11 Based on information obtained in interviews with the Director of the Energy Research and Development Institute at Chiang Mai University in Thailand.

Project discontinuation scenarios

Financial conditions for the two discontinuation scenarios are understood to be neutral, or slightly positive when considering that the costs for the operation of the treatment equipment are compulsory due to the regulations observed in the previous section. If one were to observe these costs as baseline, then the financial conditions of the discontinuation scenarios are positive due to the revenues or cost savings from use of effluent as fertiliser. If this component is discounted, on the basis that the same benefit exists for all scenarios then the financial situation is neutral.

A significant barrier for a project continuing with scenario D3 is the major upfront cost of aerobic treatment facilities. It is considered highly unlikely that facilities would write-off their investments in anaerobic treatment equipment and to re-invest in aerobic treatment equipment, except for in special circumstances where financial conditions are not the major driving force.

5.3.5 Summary of vulnerability and scenarios for wastewater projects

Table 17 gives a summary for the potential scenarios for wastewater projects in order of their financial attractiveness regarding the ongoing costs and benefits. The information in financial conditions relates only to ongoing financial flows and does not include upfront capital expenditures. Compatibility with regulations and other barriers are included in the table to help identify the most likely scenario for continuation. The financial conditions and barriers were found to not be significantly different in Malaysia, India and Thailand; the summaries for these sections in Table 17 reflect the situation for all three analysed countries.

The table shows that project continuation scenarios with utilisation of biogas for electricity or for on-site would be more attractive than the discontinuation scenarios. The continuation of mitigation activity with capture and flaring of the biogas is clearly less attractive than either discontinuation scenarios.

Table 17: Summary of conditions for scenarios for wastewater projects

Scenario	Compatible with regulations			Financial conditions	Barriers in analysed countries
	Mexico	Brazil	Thailand		
C1: Anaerobic treatment with grid connected electricity	✓	✓	✓	Extremely positive	Low (potential gird connection delays)
C2: Anaerobic treatment with on-site energy	✓	✓	✓	Positive	Variable (depending on alternative fuel availability
D2: Anaerobic treatment of wastewater with biogas release	✓	✓	✓	Neutral	None
D3: Aerobic treatment of wastewater	✓	✓	✓	Neutral	High (upfront capital costs of aerobic equipment)
C3: Anaerobic treatment with biogas capture and flaring	✓	✓	✓	Negative	None
D1: Direct effluent discharge	×	×	×	-	-

Based on the analysis as summarised in Table 17, the continuation scenarios are considered to be the most likely, and wastewater projects are therefore considered to have a low risk of discontinuation in all of the countries studied.

The analysis appears to be consistent with other assessments. Of the projects evaluated in research by Warnecke et al (2015), nearly 90 % of wastewater projects in Thailand, Malaysia and India reported to receive financial benefits, with over 60 % of all projects reporting that the benefits were sufficient for regular continuation of the GHG mitigation activity.

By comparison, the average proportion of projects reporting sufficient alternative financial benefits, across all of the CDM project types covered in the study, was 27 % (Warnecke, Day, & Klein, 2015, p. 93). Furthermore, it is understood that some respondents to the evaluation may have been likely to understate the receipt of alternative financial benefits. It is noteworthy that a relatively low proportion of wastewater projects evaluated by Warnecke et al (2015) reported to have received an overall positive return on investment, due to the high upfront capital investments. However, given the present situation that these initial capital costs are sunk, the ongoing financial conditions appear to be conducive for continued operation in most cases.

To summarise, the evidence indicates that the financial benefits of grid connected projects are far superior to ongoing costs, whilst the financial conditions for other projects are also likely to be conducive to continuation of the activity, except for in the case that only a small portion of the biogas can be utilised, and no other benefits are accrued through fertiliser replacement. Since there are conducive laws for grid connectivity in all three of the countries under investigation, it is assumed that upgrades to the generation equipment to enable grid connectivity are possible and likely, even for projects where it was not foreseen in the original project design document. Therefore, the high majority of projects in India, Thailand and Malaysia are assumed to proceed under scenario C1: *Continuation of activity with anaerobic treatment with grid connected electricity*, and are understood to have positive financial conditions.

5.4 Palm Oil Solid Waste Composting

5.4.1 Description of project type and scenarios

For the purpose of this analysis, *palm oil solid waste composting* projects are those classified as Composting by the UNEP DTU pipeline, in the palm oil sector, with methodology AMS-III.F.: *Avoidance of methane emissions through composting*. Only this one project methodology, applicable to small-scale projects, is used.

From the countries selected for analysis in this research undertaking, palm oil solid waste composting projects only exist in Malaysia, where 33 projects were successfully registered by January 2016. Outside of the selected countries, Indonesia hosts a small number of composting projects, whilst individual projects are also hosted by Colombia, Guatemala, Ghana, Philippines and Bangladesh.

The technology employed is very similar for all projects in the palm oil solid waste composting grouping, including for large scale and small scale operations. The technology and abatement methodology is summarised below, alongside continuation and discontinuation scenarios.

Table 18: Plausible continuation and discontinuation scenarios for palm oil solid waste composting projects

Project summary	***Dedicated biomass composting facilities source residues – primarily empty fruit bunches – from palm oil processing mills, and co-compost the residues to create organic fertiliser.***
Process description of CDM project activity	A composting facility obtains empty fruit bunches, and small amounts of palm oil mill effluent (POME), from palm oil mills. The biomass is shredded and then laid in rows, called windrows, on a dedicated concrete-floored composting yard, and mixed with a small amount of POME which acts as a wetting agent. The biomass is covered by a permeable cover which shields the biomass from rain water whilst allowing air to pass through. The windrows are periodically turned to ensure aeration. The biomass is left in this state for a period of 8 to 9 weeks by which time it is converted through aerobic processes to premature compost. During this time, conditions are monitored carefully for temperature, moisture and oxygen content to ensure optimum aerobic conditions. The premature compost is then cured for an approximately 3-week period under a closed roofed area to finalise the conversion to organic compost. The organic compost may then be sold to plantations for use as fertiliser. In a variation of the mitigation scenario, some projects use a dewatering system to extract solids from POME. The POME wastewater is treated separately whilst the POME solids are then composted with the residues. Use of POME solids can reduce the composting time to approximately one month.
Mitigation project continuation scenario C1	Continuation of composting activity with sale or own-utilisation of organic compost.
Mitigation project continuation scenario C2	Continuation of composting activity without sale of organic compost.

Project discontinuation scenario D1	The composting operation stops. EFBs are left on the ground and not collected.
Project discontinuation scenario D2	The composting operation stops. EFBs are burned in open burning process.
Project discontinuation scenario D3	The composting operation stops. EFBs are burnt for on-site steam.
Project discontinuation scenario D4	The composting operation stops. EFBs are used for mulch for young palms without a composting process.
Project discontinuation scenario D5	The composting operation stops. Residues previously utilised for composting are discarded. Empty fruit bunches and POME may be discarded on tipping sites, landfills and open air lagoons, respectively, where they decay and emit methane, which is uncontrolled and released.
Project discontinuation scenario D6	The composting operation stops. Palm oil processing residues are sold for alternative uses.

Source: Authors' elaboration based on interviews analysis of PDDs and Abdullah & Sulaim (2013).

Figure 7 presents a brief overview of the processes and technologies typically involved in the plausible continuation and discontinuation scenarios for palm oil solid waste composting projects, along with a comparison to the processes of potential project discontinuation scenarios. An analysis of the conditions and feasibility of these scenarios follows in the subsequent sections.

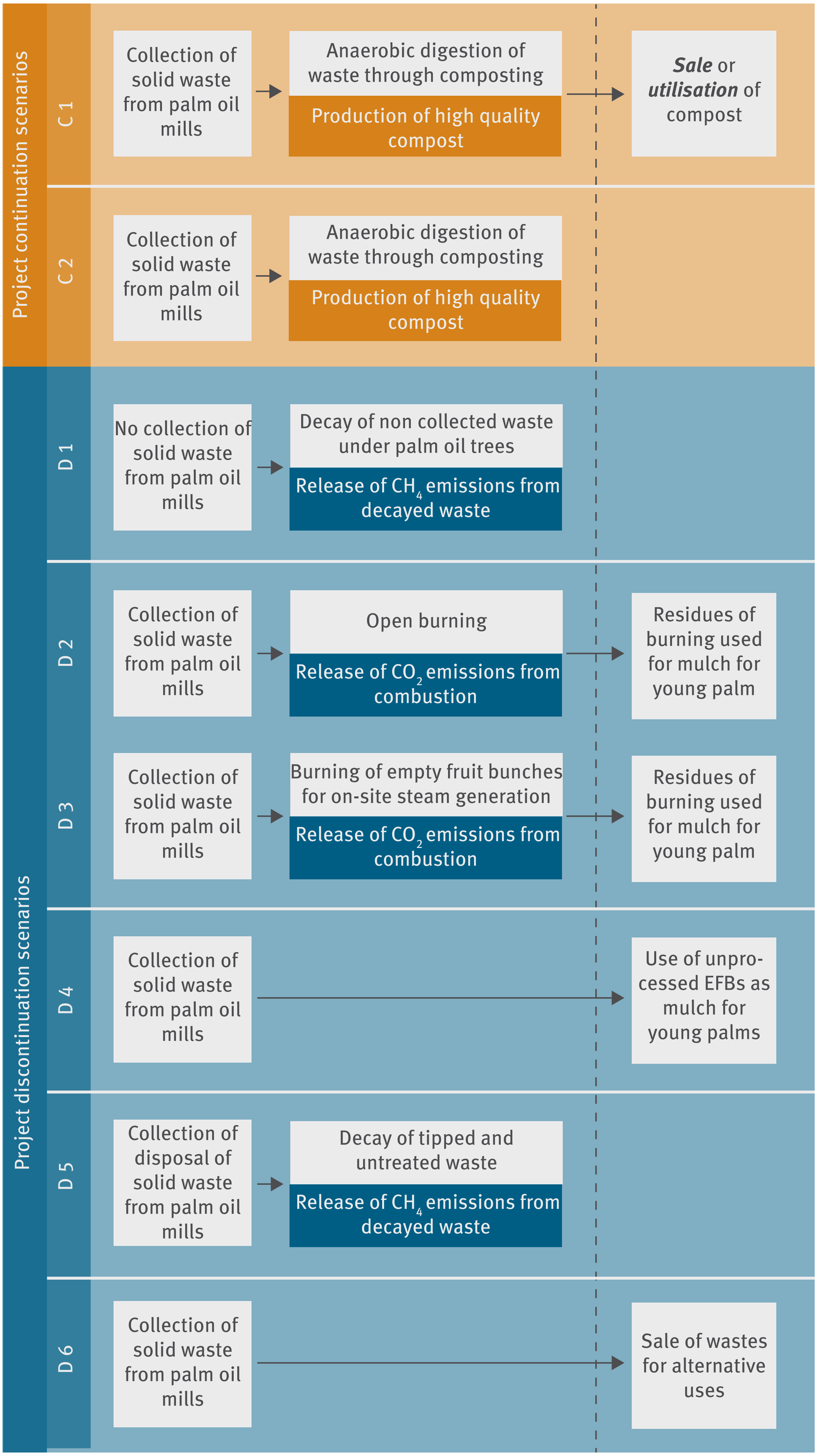


Figure 7: Overview of processes and financial implications for palm oil waste composting projects

5.4.2 Current status of projects

In research by Warnecke et al (2015), 13[12] projects for palm oil solid waste composting in Malaysia were randomly selected for evaluation. From these 13 projects, information was obtained for 12.

The information received indicated that all Malaysian composting projects initiated by a cooperation of the companies Vattenfall and Vertis Environment Finance were abandoned shortly after project registration and did not proceed to implementation. These projects account for 11 of the total 33 composting projects registered in Malaysia. Information indicates that the technical implementation of these projects never took place, so the mitigation potential is not "retrievable".

Of the remaining 21 projects, information received at the time of the evaluation, in 2014, indicated that approximately 70 % of projects were implemented with the mitigation activity in regular operation, while approximately 30 % of projects were being dismantled.

5.4.3 Overview of policy landscape

The continuation of composting project activities could be effectively enforced or heavily incentivised by policy, through regulation on the treatment of solid palm oil waste residues, including regulations against tipping of solid wastes, introduction of taxes for legalised tipping, subsidies for equipment purchase or renewal, or tax incentives for facilities that continue with composting practices.

Although parts of the palm oil industry waste in Malaysia are regulated, including regulations for the pollutant properties of palm oil mill effluent, there are no significant regulatory driven incentives for the composting of empty fruit bunches. In research by Warnecke et al (2015) none of the 12 Malaysian composting projects consulted reported that they are required to continue with the project activity due to national laws or regulations.

Only one of the identified scenarios is significantly affected by policy regulations in Malaysia. Open burning of empty fruit bunches without the generation of energy is no longer allowed (Abdullah & Sulaim, 2013). This rules out discontinuation scenario D2 from the further analysis, as indicated in Table 19.

Table 19: Compatibility of palm oil solid waste composting project scenarios with regulations in Malaysia

Scenario	Compatibility of scenarios with regulations Malaysia
C1: Composting with sale/utilisation of compost	✓
C2: Composting without sale/utilisation of compost	✓
D1: Decay of solid wastes without collection	✓
D2: Open burning of wastes and utilisation of residues for mulch	×
D3: Combustion of wastes for steam and utilisation of residues for mulch	✓
D4: Utilisation on non-processed EFBs for mulch	✓
D5: Disposal of EFBs in landfills / tipping sites	✓
D6: Sale of EFBs for alternative uses	✓

5.4.4 Assessment of costs, financial benefits and barriers

In addition to information and insights from local experts, 10 projects from different countries and industries were selected for analysis of financial conditions, according to the information included in, or attached to, their PDDs.

12 The selection of 13 projects was the outcome of an algorithm to ensure a minimum confidence level for the project type and country combinations analysed in that study (see Warnecke, Day, & Klein, 2015 Ch 2.4)

In this subsection the costs and benefits of each of the scenarios are analysed, along with other financial and non-financial barriers for the pursuance of the scenario. Costs are considered in terms of ongoing operating expenditures and maintenance for certain processes, including expenditures for labour, additional energy demand, regular purchases of process inputs, repair and replacement of parts, where necessary.

Table 20 gives an overview of the types of costs and benefits incurred by palm oil solid waste composting projects, under the scenarios identified. Closer analysis of these costs and benefits, along with potential barriers, is given for each scenario below the table.

Table 20: Potential costs and financial benefits for palm oil solid waste composting project scenarios

Scenario	Costs					Benefits			
	Collection of EFBs	Tipping fees	Operation of composting facility	Transportation of whole EFBs	Transportation of processed EFBs	Utilisation for mulch	Organic compost fertiliser	Direct sale of EFBs	Sale of mitigation equipment
C1: Composting with sale/utilisation of compost	✓		✓	(✓)	✓		✓		
C2: Composting without sale/utilisation of compost	✓		✓		✓				
D1: Decay of solid wastes without collection									✓
D2: Open burning of wastes and utilisation of residues for mulch	n.a. (Scenario not compatible with regulations – see section 5.4.3)								
D3: Combustion of wastes for steam and utilisation of residues for mulch	✓				✓	✓			(✓)
D4: Utilisation on non-processed EFBs for mulch	✓			✓		✓			(✓)
D5: Disposal of EFBs in landfills / tipping sites	✓	✓		(✓)					(✓)
D6: Sale of EFBs for alternative uses	✓							✓	(✓)

Source: Authors' elaboration based on PDD analysis, interviews and literature (Abdullah & Sulaim, 2013)

Project continuation scenario C1: Composting with sale/utilisation of compost

All public investment analyses for Malaysian palm oil solid waste composting projects report significant revenues from the sale of compost, for use as fertiliser. The price received per metric tonne of compost produced appears to be highly variable depending upon the region and the local market: of the 10 selected project analyses[13], investment analysis documents showed that the expected compost price varied from as low as USD 10 per tonne in some projects, to over USD 35 per tonne for others. Across the analysed projects, annual financial benefits of running the project activity were found to be within a large range of 12 % to 32 % of initial capital expenditure. Compost sales are usually the only significant source of financial benefit for composting projects, so the final revenue is highly dependent on the actual current market price of the compost.

13 From author analysis of 10 publicly available investment analyses of Malaysia composting projects, representing over 30 % of Malaysian composting projects.

For a small number of projects, where the owner of the palm oil mill and/or the plantation is also the project operator, part of this financial benefit is also due to cost savings from use of compost on the owners own site. However, this offers no significant diversification of financial benefits, since its value is also dependant on the local market price for compost.

The continued operation of composting facilities also incurs significant costs on an annual basis through operating expenditures and project maintenance. According to the information provided in some investment analysis documents, ongoing costs, in order of their approximate magnitude, were incurred for the procurement of empty fruit bunches, the bagging and mixing of compost for distribution, labour costs for facility operation, diesel costs for on-site energy generation, maintenance costs, land rental fees, and costs for microbe composting agents. Across the analysed projects, annual operating expenditures and maintenance costs were forecast to be within a large range of 10 % to 35 % of project capital investments. For projects where the owner of the palm oil mill and/or the plantation is also the project operator, costs for procurement of empty fruit bunches and land rental may not be applicable, although in theory there may be an opportunity cost that is not factored for in these projects since the empty fruit bunches might be possibly sold on the market, and the land could be used for other profitable activities. For all projects, ongoing costs are also highly dependent on potentially changeable conditions in the labour market and the market for empty fruit bunches.

The ex-ante assessment of investment conditions for composting projects in Malaysia shows very variable results; some projects forecast annual OPEX after the initial capital investment to be in excess of the annual financial benefits, whilst other project forecast the opposite. Of the analysed projects, forecast financial benefits were equal to 68 % of operating expenditures in the least prosperous project, and 206 % in the most prosperous project. For most projects, the difference between operating expenditures and financial benefits was very marginal, and whether or not the project continuation is actually financially attractive is very sensitive to the numerous market conditions discussed.

In research by Warnecke et al (2015), most evaluated Malaysian composting projects indicated that they had received a positive return on their investment overall to date, including from historical CER revenues and alternative financial benefits. Approximately half of the projects consulted reported that the continued financial benefits aside from CER revenues remain sufficient for continuation of the activity, whilst the remaining half of projects reported that benefits were accrued but that these alone were not sufficient for continuation. Those projects that reported insufficient contributions were also those that reported they would be dismantling, whilst the others reported that they would remain in regular operation for at least the next 12 months.

Information on the current industry situation from local experts indicates that the variability of project situations remains true now as much as it did at the point of designing the ex-ante investment analysis for the PDD. The feasibility of composting as a profitable economic activity is marred by several market challenges. Most notably, compost from palm oil solid wastes is often not accepted or trusted as a high quality alternative to imported chemical fertilisers, thereby stalling its market value considerably. This distrust is based upon the general lack of experience with these fertilisers, compared to the more established chemical fertilisers, although this is a situation that should gradually improve; an increasing volume of research and commercial projects are reporting positive experiences and a small number of large scale commercial operators have begun to use compost fertilisers.

Local experts consider it highly likely, although not certain, that the conditions for the continuation of composting for projects that already have the equipment, are positive. It is, however, not likely that new players would enter the market without support. This is also a barrier for existing operators, since the stability of the market for compost would benefit from more participation and experience.

Project discontinuation scenario D1: Decay of solid wastes without collection

Table 20 shows that scenario D1 would incur no additional costs of benefits, aside from the potential sale of mitigation equipment. Essentially, this scenario involves no action on the part of any project stakeholders.

For all of the discontinuation scenarios, there is a potential benefit from the sale of the GHG mitigation equipment, in the case that the composting facility was fully implemented under the original CDM activity. In theory, there should be a financial value for this equipment: According to ex-ante project investment analyses, depreciation of equipment is expected to take place at a rate of between 5 % and 10 % per year. By the end of the project activity, some projects report the possibility of a residual value of the initial investment, in some cases as high as 25 % of the initial investment. Realistically, there are two significant barriers to the significant resale of equipment for the recovery of capital expenditure. Firstly, the equipment is generally highly suitable for its purpose in a composting plant, and not particularly adaptable for other uses. Secondly, the major parts of the investment are built-in infrastructure, including concrete platforms and roofed areas, that cannot easily be moved to another location if sold. As such, the resale opportunity of major components from the initial investment is only realistic in the case that a prospective buyer plans to use the equipment for the same purpose and in the same location. However, it may be possible for project owners to recover small parts of the initial expenditure for some more adaptable and mobile components, especially machinery. Vehicles, such as dump trucks and heavy duty front loaders, which are used by most projects, are very easily transferable to new owners and new types of activities. For projects that use an AVC dewatering system, this equipment may also offer feasibly attainable resell value, since it may be used in a variety of de-watering applications, and is often housed within a recycled cargo container and is therefore easily transportable.

The resale of such components would recover only minimal amounts of the original capital expenditure, but may be financially attractive in the case that the project income is not significantly higher than operating expenditures.

The financial conditions for scenario D1 are considered to be neutral due to potential barriers with the resale of mitigation equipment, but otherwise positive if the barriers can be overcome.

Project discontinuation scenario D3: Combustion of wastes for steam and utilisation of residues for mulch

Solid wastes from palm oil mills are usually used on-site to generate energy for heating and electricity and can also be used for large scale electricity generation and sold to the grid. The most important solid wastes for energy generation processes are palm kernel shells and fibre, which can be supplemented by smaller amounts of EFB. This is unlikely to make a significant impact on composting activities, and the attractiveness of any of the other scenarios analysed here, since only a small proportion of the EFB waste produced can be used for this purpose. Even in the case that this scenario is the most attractive, this only affects some of the EFBs, whilst the remaining scenarios still need to be analysed for the fate of the majority of the waste.

Indeed, usually it is the case that EFBs are used as input for energy generation, whilst other means of disposal or utilisation are pursued in parallel. This is, in some cases, also a parallel process in the mitigation activity scenario, and could therefore be considered a parallel process for any of the continuation or discontinuation scenarios analysed. Therefore, scenario D3 is no longer considered an alternative scenario.

Project discontinuation scenario D4: Utilisation on non-processed EFBs for mulch

The benefits of using EFBs for mulch are understood to be significant, although not cost-effective due to the high transport costs of non-processed EFBs (Abdullah & Sulaim, 2013). Therefore, the financial conditions for scenario D4 are considered to be negative.

Potential sale of mitigation equipment may increase the attractiveness of the scenario slightly, but some of the most easily transferable equipment, such as vehicles, may still be needed for this scenario. As such, this potential benefit is unlikely to be highly significant.

Project discontinuation scenario D5: Disposal of EFBs in landfills / tipping sites

Table 20 shows that scenario D5 incurs a number of costs, without any significant benefits. The costs incurred are similar as those for scenario D4, in the collection and transportation of EFBs. Furthermore, tipping fees may be payable for disposal in designated waste disposal facilities.

There are no financial benefits for this scenario aside from the potential sale of mitigation equipment. The same barriers are faced as those discussed for other discontinuation scenarios. Like for scenario D4, the some of the most easily transferable equipment, such as equipment for collection and vehicles for transportation of waste, may still be needed for this scenario. As such, this potential benefit is unlikely to be highly significant.

Financial conditions for scenario D5 are considered to be very negative.

Project discontinuation scenario D6: Sale of EFBs for alternative uses

There are various alternative options for the use of empty fruit bunches (EFB) (Abdullah & Sulaim, 2013):

- Paper production – EFB can be used as input for thin and high quality papers.
- Basic road surfacing material – EFB are used on some plantations to mark and surface basic roads, to save costs from other materials.
- Production of medium-density fibreboard (MDF) and blackboards – Some companies in Malaysia have made considerable investments in developing technologies for EFB-based MDF. Further research is ongoing with regards to the use of EFB for high-density fibreboard (HDF) which may be used for applications such as floorboards.
- Briquettes – The production of EFB briquettes may be an attractive option although EFB briquettes may have difficulties to compete on domestic markets due to the wide availability of charcoal and wood fuel.
- Hydrogen fuels – The gasification of EFB may have the potential to produce high quality hydrogen fuels for transportation. This technology is, however, only at the very early stages of research in Malaysia.
- Biomass energy – EFBs may play a small role for biomass energy in combination with other biomasses. A small proportion of EFBs are usually utilised for on-site heat energy, as previously described, but the use of all EFBs for heat energy on multiple sites is not viable due to the high transportation costs relative to the energy value.

The financial attractiveness of these options depends on local market conditions.

Local experts indicate that the viability of the alternative uses of EFB are highly variable over time and regions, as none of the alternative markets are maturely established. The financial conditions for the sale of EFBs are considered generally positive, although market possibilities will not exist in all cases, at all times.

5.4.5 Summary of vulnerability and scenarios for palm oil solid waste composting projects

Table 21 gives a summary for the potential scenarios for palm oil solid waste composting projects in order of their financial attractiveness regarding the ongoing costs and benefits.

Table 21: Summary of conditions for scenarios for palm oil solid waste composting projects

Scenario	Regulatory compliance	Financial conditions	Non-financial barriers in Malaysia
C1: Composting with sale/ utilisation of compost	✓	Usually positive	Highly variable conditions between region and over time due to non-maturity of market for palm oil solid wastes
D6: Sale of EFBs for alternative uses	✓	Positive	Lack of demand in all regions at all times due to non-maturity of alternative markets
D1: Decay of solid wastes without collection	✓	Slightly positive (with sale of mitigation equipment)	None
D4: Utilisation on non-processed EFBs for mulch	✓	Negative	None
D5: Disposal of EFBs in landfills / tipping sites	✓	Highly negative	None
C2: Composting without sale/utilisation of compost	✓	Highly negative	None
D2: Open burning of wastes and utilisation of residues for mulch	×	-	-
D3: Combustion of wastes for steam and utilisation of residues for mulch	n.a. Not considered an alternative scenario. Occurs in parallel with all other scenarios.		

As previously discussed, at least one third of the 33 projects are known to have never entered implementation, so the assessment of continuation or discontinuation scenarios applies only to the remaining two thirds of projects. Table 21 shows that the continuation scenario with sale or utilisation of compost is still likely to be the most attractive option for implemented projects. However, this verdict is generalised and the actual fate of projects is highly dependent on the regional market. The immature status of the EFB compost market, means that the market conditions vary considerably between regions, and the feasibility of some projects will depend largely on the deals that can be made between the project operator and other local agricultural businesses, some of which are becoming more interested in EFB compost whilst most still prefer to use chemical fertilisers. Due to the lack of regulation or stability in the market, the conditions can also change considerably over short periods of time.

In the case that scenario C1 in not financially attractive due to local market conditions, there are two discontinuation scenarios that also entail potentially positive conditions: the sale of EFBs for alternative uses, and the decay of solid wastes without collection, both including the partial resale of equipment purchased for the implementation of the composting activity.

The risk of project discontinuation for composting projects in Malaysia is identified as uncertain, due the variability of conditions. Although many projects are likely to continue, there is considerably uncertainty and many projects are understood to be in the process of dismantling (Warnecke, Day, & Klein, 2015).

5.5 Summary of vulnerability for methane avoidance projects

The analysis of methane avoidance projects has demonstrated major differences in the conditions and prospects of different project subtypes.

Table 22 summarises the conditions for methane avoidance projects.

- Commercial livestock manure management projects are known to have faced considerable difficulties in Mexico and Brazil due to third party ownership issues, resulting in at least 88 % and 58 % of projects in these countries, respectively, being already dismantled. The remaining projects are mostly likely to have had the same fate, whilst the farms where technologies are installed are at a high risk of discontinuing, if they have not done so already. All manure management projects in Thailand utilise biogas for electricity and do not face the same barriers regarding ownership structures and capacities for technology operation as projects in Mexico or Brazil, and as such are considered low risk.
- Wastewater projects are understood to be at low risk of discontinuation in India, Thailand and Malaysia due to the high benefits of biogas utilisation, and the recent availability of grid connectivity in these countries.
- The risk of project discontinuation for composting projects in Malaysia is identified as *uncertain*, due the variability of conditions. Although many projects are likely to continue, there is considerably uncertainty due to changeable local market conditions and the immaturity of the EBF compost market, and many projects are understood to be in the process of dismantling.

Table 22: Summary of vulnerability of methane avoidance projects

	Mexico	Brazil	India	Thailand	Malaysia
Commercial livestock manure	High risk › 88 % already dismantled	High risk › 58 % already dismantled	Not evaluated	Low risk	Not evaluated
Wastewater	Not evaluated	Not evaluated	Low risk	Low risk	Low risk
Palm oil solid waste composting	Not evaluated	Not evaluated	Not evaluated	Not evaluated	*Uncertain*

6 Biomass energy – assessment of project discontinuation risk

6.1 Overview of project type and identification of groupings for analysis

Biomass energy projects include projects that utilise biomass-based fuels for energy generation and use. In this research, the term biomass includes both renewable biomass as well as biomass residues.

The UNEP DTU pipeline categorises biomass energy projects into 12 subtypes on the basis of the type of biomass. This subtype division based on the biomass type does not offer a categorisation which is particularly distinctive in terms of the mitigation activities undertaken, and as such does not provide a useful categorisation for assessment of their vulnerability. Upon detailed review of the biomass energy projects and insights of local experts, it was observed that several local conditions impact biomass energy projects. These include: security of fuel availability, which is linked to the biomass ownership and supply chains; technology modifications to suit biomass type; generated energy use; industry characteristics; domestic regulatory regimes etc. Therefore, it was decided to deviate from the UNEP-DTU classification and re-categorise biomass energy projects considering the type of industry, the type of biomass used, and whether the energy generated is used on-site or fed into the grid. The categorisation and specific explanations for the derivation of the sub-types are provided in *Annex I – Subtype categorisations*.

Next, three distinct sub type-country groupings were identified for further analysis based on countries that host the largest number of projects in the biomass energy project type. These are:

1. **Bagasse energy in the sugar industry, with a focus on Brazil and India:**
   This category covers biomass energy projects developed in the sugar industry. All of them use bagasse i.e. the fibrous residue of sugarcane stalks generated after extraction of sugarcane juice in sugar manufacturing process. The projects can be cogeneration or heat generation only or power generation only; and with or without sale of power.
   Projects using sugarcane bagasse in other industries for heat only/power only/cogeneration for independent power production or captive are covered in categories 2 and 3 respectively.
2. **Independent electricity production from biomass, with a focus on Thailand and India:**
   This category includes independent power projects that export electricity to the grid or sell it to a third-party, thus replacing need for fossil fuel based generation in the grid or at the third party. An independent power producer is a private entity that owns and operates facilities for the generation of electricity. An IPP can be standalone, i.e. it is a standalone power generation company with electricity sale the only business of the project owner, or associated to an industrial facility as a subsidiary, Joint Venture, associated company etc. Projects are for power generation only, with no heat or cogeneration. The biomass types covered include agricultural residues (e.g. rice husk, mustard stalks, poultry litter, etc.), forestry biomass, forestry residues (e.g. generated in the process of fuelwood and charcoal production), industrial bio-residues (e.g. saw mill wastes, bagasse etc.), and other biomass residues (municipal solid waste, animal wastes etc.).
3. **Other biomass energy projects with captive energy use, with a focus on India:**
   This category includes all other biomass energy projects which generate and use electricity and/or steam and use the electricity and/or steam on-site at an industrial facility, with no export to the grid. Both heat generation only, power generation only and cogeneration projects are covered. The biomass types as well as the generation technologies covered are the same as in the previous category. Biomass/biomass residues can be the project developer's own or procured from elsewhere. The energy generation could occur in a boiler or through gasification of the biomass and subsequent combustion. Biomass energy projects developed in the sugar, palm oil and cement industries are excluded here. These are grouped separately due to their conditions being considered quite unique. Further details on the full categorisation can be found in *Annex I – Subtype categorisations*.

These groupings are presented in Table 23 along with the number of projects in each of the countries.

Table 23: Overview of biomass energy project categories for analysis

Country	Bagasse energy in sugar industry	Biomass based Independent electricity production	Other biomass energy projects with generation and captive use
India	44	114	114
Thailand	4	22	0
Malaysia	0	7	14
Pakistan	1	0	1
Mexico	2	0	0
Brazil	27	7	10
South Africa	1	2	2
Kenya	1	0	0
Total[14]	**80**	**152**	**141**

14 Refers to total projects in the 8 selected countries.

6.2 Bagasse energy in the sugar industry

6.2.1 Description of project type and scenarios

This category covers biomass energy projects developed in the sugar industry using bagasse. The majority of bagasse energy projects have been registered in India and Brazil. They together host 74 % of all registered bagasse energy projects in the CDM pipeline and 89 % in the countries shortlisted for this research. Brazil and India are also the largest producers of sugar globally. The uptake of bagasse energy projects is less prominent elsewhere due to moderate sugar production and generally lesser CDM activity in this sector. Only 28 registered projects come from the remaining 18 host countries.

Projects use methodologies ACM0006, AMS-I. C and AMS-I. D. Over three-quarters of the projects are large-scale and the rest small-scale. CDM project activities are either construction of new energy generation unit/s; or replacement / expansion of existing units.

In the assessed countries, bagasse energy projects have the following characteristics:

- **Projects utilize bagasse as the primary fuel for energy generation.** Projects usually utilize their own bagasse generated during the cane crushing season. The production of bagasse depends on sugarcane production. One planting season typically lasts six to eight months; the planting months differ according to regions. Therefore, some projects may procure additional biomass.
- **Projects produce energy through cogeneration.** Although bagasse energy projects can be cogeneration (i.e. simultaneous generation of energy and power), heat generation only and power generation only, all projects in our assessed countries were cogeneration.
  As the sugar industry has an internal steam demand, power only projects are a rare possibility. Therefore, only cogeneration projects are considered in the analysis. Historically, India and Brazil have had low pressure boilers.
- **A major portion of the electricity output is sold to third-parties, usually the grid.** Most projects export power to the grid or sell it to a third-party. A small portion of the generated energy is used for meeting the on-site demand. If the project is developed in a sugar mill, this demand is largely from the sugar manufacturing process. If the project is developed in an integrated facility (i.e. one with a sugar mill and distillery for bioethanol production), energy demand is from both.

While precise technology specifications may differ, all bagasse energy projects employ cogeneration technology in which bagasse is burned in a high pressure boiler to generate steam which is expanded in a turbine to produce electricity. The expanded steam is used for meeting the process energy needs of the plant. The technology and abatement methodology is summarised in Table 24 below, along with the project continuation and discontinuation scenarios.

Table 24: Plausible continuation and discontinuation scenarios for bagasse cogeneration projects.

Project summary	***Bagasse is used as the primary fuel for energy generation. The energy output (heat and electricity) is used to meet on-site energy needs and sold to a third-party, usually the grid***
Process description of CDM project activity	The bagasse used is produced on-site or procured from nearby sugar factories and has about 40-50 % moisture. It is stored under aerobic conditions in piles in a storage yard. No methane emissions are expected during storage as bagasse degrades slowly and is generally used within a year. In these piles, bagasse dries naturally and no additional mechanical or thermal treatment is required for fuel preparation. Bioenergy conversion is typically carried out through direct combustion of the dried bagasse in a high pressure boiler to generate steam. This generated steam can be expanded through a turbine for producing electricity, while the effluent high pressure steam (in case of a backpressure turbine) or process steam (in case of a condensing-extraction steam turbine) is used for meeting industrial process heating needs. A small portion of the produced electricity is used for on-site demand while a substantial part of the produced electricity is exported to the regional grid.
Mitigation project continuation scenario C1	Energy generation continues using bagasse for both on-site energy use and grid export
Project discontinuation scenario D1	All bagasse is sold to third-parties while own electricity and heating needs are met through grid power and other fuels.

Project discontinuation scenario D2	Some bagasse is used to run the cogeneration unit to meet on-site power and thermal energy needs, while the rest is sold to third parties.
Project discontinuation scenario D3	Some bagasse is used to run the cogeneration unit to meet on-site power and thermal energy needs, while the rest is disposed of or allowed to decompose in the storage yard.

Source: Authors' elaboration based on interviews and analysis of project design documents.

Figure 8 presents a brief overview of the processes and technologies typically involved in the plausible continuation and discontinuation scenarios for bagasse energy projects in sugar industry, along with a comparison to the processes of potential project discontinuation scenarios. An analysis of the conditions and feasibility of these scenarios follows in the subsequent sections.

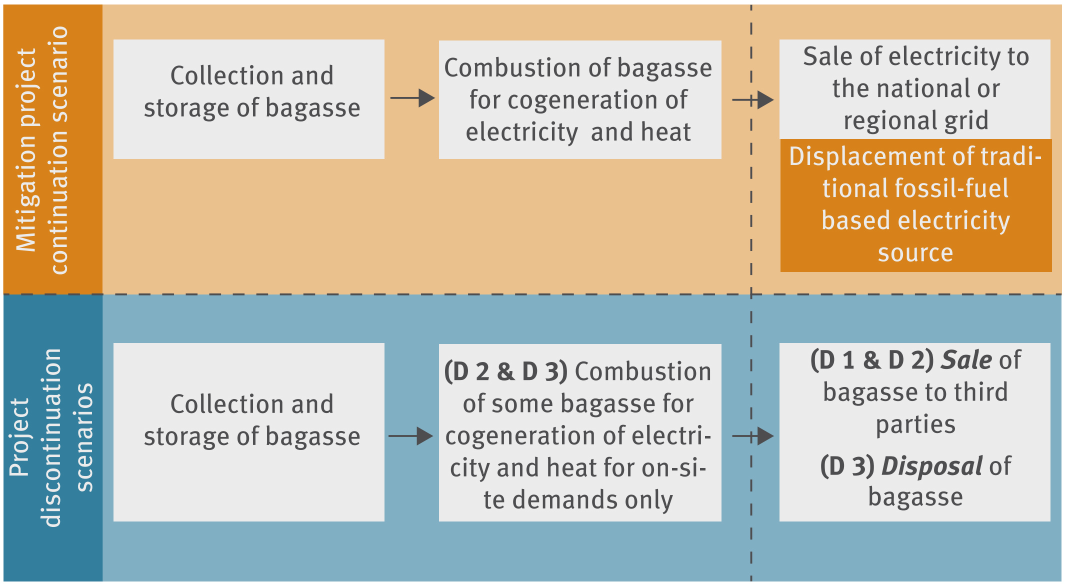


Figure 8: Overview of processes for plausible scenarios for bagasse energy projects

6.2.2 Current status of projects

Information on the current status of projects in 2014 was recorded in Warnecke et al. (2015) for at least 26 bagasse cogeneration projects worldwide.

100 % of projects were fully implemented in 2014. Of these, 73 % remained fully operational. The rate of continued operation appears to vary between countries. In India ten of eleven projects consulted remained in full operation, whilst in Brazil just two of seven projects were operational, whilst three were temporarily stopped and two continued but with non-CDM conformant operation. It is unclear to what extent the trend is significant at the country level due to the small number of projects for which information was obtained.

Overall, for all countries, approximately 70 % of projects reported that they received alternative revenues that were sufficient for continuation without CDM revenues; this proportion is far higher than for other project types.

6.2.3 Overview of policy landscape

Continuation of the mitigation activity can be influenced by regulations which mandate use/disposal of bagasse or policies which promote cogeneration. In our review, no specific policies were found mandating bagasse usage or disposal. However, many countries have policies to promote bagasse based cogeneration through fiscal and financial incentives (NewClimate Institute, 2016). For example, preferential tariffs for bagasse-based power generation provides an additional, stable revenue stream to project owners. Further, in many countries the sugar industry has diversified into biofuel production using sugar. In such cases, policies promoting or mandating biofuel production and use can also incentivise continuation of cogeneration project activities as these increase the on-site energy demand for the industrial facility that owns the project.

Table 25: Regulations for bagasse energy projects in Brazil and India

	India (44 projects)	Brazil (27 projects)
Regulations explicitly mandating usage or disposal of bagasse	×	×
Policies incentivising continuation of mitigation	✓ Preferential tariffs; Mandatory bioethanol blending and purchase policy	✓ Auctions for biomass power; bioethanol blending program

The current regulatory setup in India supports continuation of bagasse cogeneration projects through provision of preferential tariffs for grid connected bagasse based power projects. The tariffs are set at the sub-national level and are revised on their discretion. Power is procured under a long-term power purchase agreement (PPA) between distribution companies and the power producer. Tariffs are aimed at incentivising renewable power producers and are set based on benchmarked values of actual variables that affect power generation costs for a producer (such as the CAPEX, OPEX and fuel costs)[15]. The national biofuel policy also encourages cogeneration in integrated sugar factories. Molasses, another by-product of sugar industry, is commonly used as feedstock for bioethanol production in India. The mandatory biofuel blending policy directs oil marketing companies to purchase bioethanol from distilleries (mostly sugar factories) as per a minimum purchase price. In such cases, the cogeneration unit supports the additional energy demand coming from the distillery.

13.5 % of Brazil's energy mix is sugarcane based and in the form of bagasse power and bioethanol. Biomass energy, specifically through bagasse cogeneration, has been prioritised under governmental policy in the past decades due to rising concerns with regards to the continuity of hydropower. Feed-in-tariffs (FIT) adopted under the PROINFA policy in early 2000s were superseded by technology specific auctioning under the legal mandates of the 2004 Electricity Law[16]. The National Climate Change Plan (Decree 6233 of 2007) also set forth a goal for increasing the share of electricity produced from cogeneration, mainly from sugarcane bagasse, to 11.4 % of total supply in 2030 (IRENA, 2015a). Brazil was also one of the first countries to have biofuel blending mandates and the current blending rate is among the world's highest. With falling international sugar prices in the past years, a large share of total recoverable sugars has been diverted to bioethanol production. Cellulosic ethanol production, i.e. from bagasse, is still at its infancy (MME, 2014). In the current situation, sugarcane bagasse provides most energy needs for sugarcane based bio-ethanol production[17].

Table 26: Compatibility of bagasse energy scenarios with policy landscape in India and Brazil

Scenario	India	Brazil
C1: Energy generation continues using own bagasse for both on-site energy use and grid export	✓	✓
D1: All bagasse is sold to third-parties, while own electricity and heating needs are met through grid power and other fuels.	✓	✓
D2: Some bagasse is used to run the cogeneration unit to meet on-site power and thermal energy needs, while the rest is sold to third parties.	✓	✓
D3: Some bagasse is used to run the cogeneration unit to meet on-site power and thermal energy needs, while the rest is disposed-off or allowed to decompose in the storage yard.	✓	✓

15 In addition, fiscal and financial incentives are put in place on new high efficiency equipment which meets national and international standards. Policy support includes a 10-year income tax holiday, custom and excise duty concessions for some components, accelerated depreciation of 80 % in the first year and concessional loans. Support differs based on the ownership of the facilities (privately owned, cooperative or state owned).

16 The first reserve auction for biomass was held in 2008.

17 2008 situation suggested in (FAO, 2008), confirmed by interviews as current situation.

6.2.4 Assessment of costs, financial benefits and barriers

Using financial information provided in a sample of PDDs, the following sub-section provides an assessment of the costs and benefits of each of the previously outlined scenarios, along with other financial and non-financial barriers for the pursuance of the scenario. Costs considered are those contributing towards energy production and include costs of operation and maintenance of equipment related to energy generation and export; administrative expenditures and personnel costs; fuel purchase and transport costs; and expenditure on process chemicals used in boiler and cooling towers, as applicable. The financial benefits are in the form of direct revenues from the sale of electricity to the grid. In cases where electricity would be bought from the grid in the absence of the CDM activity, indirect benefits are gained in the form of avoiding this expenditure. Although not taken into account in the PDDs, sale of bagasse ash as fertilizer can be another revenue source for some project developers.

The costs and benefits of all scenarios are compared to the most typical pre-project or baseline scenario in PDDs: the bagasse is used to co-generate electricity and steam; the electricity is only used on-site and not be fed into the grid; no other fuels are being co-fired; during the off-season, own energy needs may be met through procurement of biomass or alternative fuels.

Table 27 presents an overview of the potential costs and benefits from the plausible scenarios. The following sub-sections delve into the details of these costs and benefits, and potential barriers.

Table 27: Potential costs and financial benefits for bagasse energy project scenarios

Scenario	Operation and maintenance costs						Benefits			
	O+M of cogeneration and feeder equipment	O+M of grid connection equipment	Fuel procurement (off-season)	Electricity purchase	Alternative fuel purchase	Disposal of bagasse	Sale of electricity	Sale of boiler ash as fertiliser	Sale of bagasse	Sale of electricity generation equipment
C1: Energy generation for on-site and power export with bagasse continues	✓	✓	(✓)				✓	✓		
D1: All bagasse sold to third parties				✓	✓				✓	✓
D2: Bagasse partially used for on-site energy needs, with remainder sold	✓							✓	✓	
D3: Bagasse partially used for on-site energy needs, with remainder disposed	✓					✓		✓		

Source: Authors' elaboration based on PDD analysis, interviews and literature

Project continuation scenario C1: Energy generation continues using bagasse for both on-site energy use and grid export

The main costs in scenario C1 are incurred in the operation and maintenance of the cogeneration unit and feeder equipment. Compared to a pre-project scenario, grid connected cogeneration plants also bear additional operation and maintenance costs for power transmission equipment and, depending on contractual arrangements with the seller, can include costs towards maintenance of transmission lines, transformers, switch lines etc. These costs are reported to be nearly of the same order as the O&M costs for cogeneration units in the assessed PDDs.

Since cogeneration is a common practice in sugar industries of both countries, no significant additional expenses are borne towards administrative overheads and personnel expenses over those in the absence of the CDM project. The other significant costs may come from the need to purchase biomass for export electricity generation in the off-season. Sugarcane is a seasonal crop, thus, bagasse availability is not perennial for factories, especially those having lower cane crushing capacity. Additional fuel purchase costs (bagasse or other biomass residues) for the off-season may be borne by the developer to maintain power export. When incurred, these can account for over three-quarters of the annual costs for the project owner.

All projects in our sample forecasted higher revenues than annual power generation costs in their ex-ante project investment plans in PDDs. On average, the annual revenues from electricity sales reported by projects in their ex-ante investment analyses amount to over 200 % of the annual operating expenditure for energy production. Even greater benefits are reported if there were no additional fuel purchase costs. Electricity sale forms the main revenue in continuation scenario C1. In most cases, electricity is sold to the regional grid, although some projects also sell power and heat to neighbouring facilities. The current situation of such projects is dependent on revenues from tariffs set by regulators. In India, feed-in-tariffs segregated based on type of renewable energy are set by sub-national regulatory agencies. The expected bagasse cogeneration tariffs ranged between INR 2.9-3.5/kWh (~USD 0.07/kWh) in the assessed Indian PDDs[18]. In Brazil, most grid exporting bagasse cogeneration CDM projects appear to be conceptualised during the PROINFA policy (around 2006-07). The minimum tariff provided under this policy has been BRL 83.58 /MWh or USD 0.04 /kWh (IRENA, 2015a). The only Brazilian PDD undertaking an investment analysis[19] quotes BRL 125/MWh (~USD 0.06/kWh), about 150 % higher than the floor price. Biomass tariff have also been gradually increasing. In the auctioning phase, an average tariff of USD 0.08/kWh would have been provided (Maurer & Barroso, 2011) and the average auctioning price for biomass projects in latest biomass auctions is quoted to be BRL 235.95/MWh or ~USD 0.11 /kWh (argus, 2016). Best available estimates of feed-in-tariff in India are of the order of INR 3.5/kWh[20] (~USD 0.05/kWh). Some states encourage biomass energy and regularly revise their tariffs (e.g. the 2015-16 tariff order by the State Regulatory Commission of Punjab sets tariff of INR 6.41/kWh (~ USD 0.09 kWh) for non-fossil based co-generation projects (PERC, 2015)), while many have not changed their tariffs for years).

This review of the current tariffs indicates that the comparison of revenues to operating costs as presented in the initial investment analyses of PDDs remains relevant for both Indian and Brazilian projects, although conditions vary significantly between local regions due to biomass markets and varying tariff levels, so such conclusions can only be generalised. In India, the current average feed-in tariffs are found to be at the top end of the range assumed by PDDs, so it can be assumed that revenues will be no lower than those forecasted in the PDDs. Also in Brazil, the floor price of the PROINFA policy, although slightly lower than the assumed tariffs in the only PDD for which the information was available, would still result in revenues that are more than 3 times greater than the costs for that specific project; it is understood that such findings are representative of other projects in the country. Furthermore, in practice, the information previously presented indicates that actual tariffs received by projects in Brazil are likely to be considerably larger than this floor price.

In addition to benefits from sale of power, the project developer can also sell bagasse ash produced in the cogeneration process as a fertiliser (e.g. used with press mud) or input to other industries (e.g. in brick manufacturing).

Beyond financial feasibility, there could be regulatory compulsions to sell power to the grid under the power purchase agreements (PPAs). These contractual agreements define the commitment for power provision as well as the agreed tariffs and liabilities on breach of contract. For example, in Brazil, if producers cannot supply the agreed power, they have to buy it from the spot market to fulfil the shortfall. In India as well, inability to provide power can lead to penalties and in some cases termination of contracts.

Energy from biomass cogeneration is also seen positively if the sugar producer already produces or plans to expand into alcho-chemical production, as cogeneration can provide for the additional energy needs from the distillery.

18 For projects registered between 2007-2012

19 Most Brazilian PDDs take a barrier analysis approach for proving additionality.

20 2010-11 values based on (Gupta, 2015). Many states have not changed the tariff rates in the past years.

The assessment of revenues and costs expected in scenario C1 gives a very strong indication towards financial feasibility if projects take this route. A caveat to this conclusion is that there might be local barriers that decrease the appetite of a project owner to continue mitigation in its originally conceived manner. These barriers may include: institutional barriers in the form of irregular payments by some distribution companies; policy complexity (e.g. competitive design of auctions in Brazil); lack of predictability in the policy environment (e.g. nature of tariff setting in India); high costs of off-season biomass residues; or bagasse demand from other industries.

Project discontinuation scenarios

In scenario D1, all bagasse is sold, while the project owner procures other fuels and electricity to meet its on-site energy needs. The financial favourability of this option would depend upon the comparative costs of energy production from other fuels and electricity purchase as compared to on-site energy production. Taking the example of India, one can see that this option is financially not lucrative. Firstly, the price obtained for the sale of biomass is not consistent. For example, in a good cane season, bagasse can be sold to third-parties, mostly paper industry, at a good price of INR 2000 to INR 3000 / tonne[21] (~ USD 29 – 44 / tonne). However, there is limited certainty of a fair price due to the lack of a regulated market. Further, the costs of procuring other fuels for own use might outweigh profit from bagasse sale. The current off-season biomass costs have been quoted to be around INR 3500/tonne (~USD 52/tonne) by the sugar industry (CERC, 2015). Coal can also be expensive, with prices fluctuating daily based on international prices. The current landed costs of higher quality coal stand at around INR 3,500/tonne, although cheaper and lower grade coal may also be available[22]. Additionally, grid power costs are more or less comparable to own generation. Purchasing grid power costs around INR 6/kWh to INR 8/kWh[23] (~USD 9-12/kWh); while the approximate costs for on-site bagasse co-generation, based upon the 2015-2016 tariffs proposed by CERC and including levelised fixed costs and variable costs, are comparable or even slightly lower at INR 5.59/kWh to INR 6.97/kWh[24] (~USD 8-10/kWh), although some industry stakeholders argue that the CERC proposals underestimate the actual costs. Using other fuels in a bagasse based boiler may also increase the equipment operation and maintenance costs. Overall, insights from local experts confirm that the costs for purchasing electricity from the grid and other fuels for steam generation are likely to exceed potential revenues from sale of bagasse and the potential sale of the electricity generation equipment.

In scenario D2, the cogeneration unit is run just enough to meet on-site heat and power demand while the rest of the bagasse is sold to get some financial benefit. Whilst the sale of bagasse may make the financial conditions for this scenario positive in theory, the conditions may not be as lucrative as in scenario C1 since the price fetched for bagasse is highly unlikely to exceed the potential revenue from electricity export. Furthermore, similar to D1, owners can face difficulties in selling and getting the right price for bagasse as a regulated market for sale of biomass residues does not exist.

In scenario D3, some bagasse is used to run the cogeneration unit to meet on-site power and thermal energy needs, while the rest is disposed of, or allowed to decompose in the storage yards. This scenario would increase costs for disposal, including for transportation of bagasse to disposal sites. Further, projects developers in both countries are aware of the commercial value of bagasse, and hence selling the bagasse (scenario D1, D2) would be economically more attractive than its disposal.

Overall, none of the discontinuation scenarios seem to be financially attractive way forward for bagasse projects and face barriers in realisation.

6.2.5 Summary of vulnerability and scenarios for bagasse energy projects in the sugar industry

Table 28 gives a summary for the potential continuation and discontinuation scenarios for bagasse cogeneration projects in the order of their financial attractiveness with regards to operational costs and benefits. Compatibility with regulations, potential barriers and other considerations that have a bearing on a scenario are also included.

21 Based on bagasse selling price stated in (Das & Das, 2014) and (CERC, 2015).

22 Current coal costs were provided by interviewees, price of off-season biomass and bagasse are taken from (CERC, 2015). All figures reflect 2015 values.

23 Price information based on actual prices offered to industrial users in 2015 obtained from interviews.

24 Based on information in (CERC, 2015).

The table shows that the scenario C1 with continuation of energy generation and sale of power is likely to be the financially most attractive option for the implemented projects. However, the actual fate of projects may differ due to local dynamics such as the informal market, nature of PPAs etc.

Unfavourable market conditions might lead to a decision to discontinue the project activity. Of the potential discontinuation approaches discussed, discontinuation scenario D2, where some bagasse is used to run the cogeneration unit to meet on-site energy demand and selling the rest to third parties, might be a pursuable option financially. However, the price one can get from bagasse sale is not same everywhere and every time. Between C1 and D2, the predictability of revenues is higher in C1 as PPAs are formalised, long term contracts.

Keeping these considerations in mind, the generic risk of project discontinuation for bagasse cogeneration projects in India and Brazil's sugar industry is concluded to be *Low*.

Table 28: Summary of assessment of bagasse energy projects in the sugar industry

Scenario	Regulatory compliance		Financial conditions	Barriers and other considerations
	India	Brazil		
C1: Energy generation for on-site and power export with bagasse continues	✓	✓	Very positive	▸ Potential regulatory compulsions to sell power to the grid ▸ Cogeneration favourably if sugar producer expands into alcho-chemical production, due to energy provision. ▸ Irregularity in payment for exported power by some procurers and complex policy environments
D2: Bagasse partially used for on-site energy needs, with remainder sold	✓	✓	Slightly positive / neutral	▸ Presence of informal market doesn't guarantee price certainty for selling bagasse
D1: All bagasse sold to third parties and own electricity and heating needs are met through grid power and other fuels.	✓	✓	Neutral / slightly negative	▸ Presence of informal market doesn't guarantee price certainty for selling bagasse and purchasing other fuels at a fair price. ▸ Fuel purchase agreements are usually not long term
D3: Bagasse partially used for on-site energy needs, with remainder disposed	✓	✓	Negative	

6.3 Independent electricity production from biomass

6.3.1 Description of project type and scenarios

This category includes independent power projects that export electricity to the grid or sell it to a third-party, thus replacing need for fossil fuel based generation in the grid or at the third party. An independent power producer (IPP) is a private entity that owns and operates facilities for the generation of electricity i.e. a power generation company with electricity sale as the only business of the project owner[25].

25 Another possibility of an IPP can be when an industrial facility also acts as an independent power producer or when a renewable power company is associated to an industrial facility as a subsidiary, Joint Venture, associated company etc. Both these scenarios are excluded from the analysis as these are less commonly followed and constitute about 7% of the IPP projects in selected countries.

The biomass types covered include agricultural residues (e.g. rice husk, mustard stalks, poultry litter, etc.), forestry biomass, forestry residues (e.g. generated in the process of fuelwood and charcoal production), industrial bio-residues (e.g. saw mill wastes, bagasse etc.), and other biomass residues (municipal solid waste, animal wastes etc.). Biomass is usually procured from elsewhere.

Projects typically use methodologies for generation and export of power to the grid (ACM 6, ACM 18 and AMS I D). Projects dealing with poultry litter additionally use methodologies for mitigation by avoidance of methane production from decay of biomass (AMS III E) and GHG reductions/methane recovery from animal manure systems (ACM 10 and AMS III D). Over 90 % projects are small scale.

The current analysis focusses on projects from India and Thailand. They together host 95 % of similar projects in the countries shortlisted for this research and form approximately 18 % of the biomass energy CDM projects. India is the country with the largest portfolio of projects, with approximately 114, compared with 22 in Thailand. Projects in India typically use rice husks and Prosopis juliflora, whilst projects in Thailand use a larger variety of agricultural and forestry residues, including prominently wood chips and rice husks.

The majority of projects take the combustion route for bioenergy generation in which the biomass is burnt in a high pressure boiler to generate steam which is further used for electricity generation.

A few projects could involve gasification by undertaking a controlled burning of biomass to generate producer gas which is then used for power generation. The typical technology and abatement methodology for this sub-type is summarised in Table 29 below along with the project continuation and discontinuation scenarios.

Table 29: Plausible continuation and discontinuation scenarios for biomass IPP projects.

Project summary	***Biomass is used to generate electricity, which is sold.***
Process description of CDM project activity	A typical CDM activity involves procurement of biomass / biomass residues from nearby agricultural fields or fuel collection centres. The semi-processed biomass/biomass residues are transported to the project site, where they are stored in storage facilities. Preliminary biomass processing in the form of cutting, drying and bailing may be done at the point of generation of the biomass to increase their bulk density and transportability. Due to a seasonal supply of biomass, project owners invest in storage facilities on-site. Further processing is typically required on-site for most biomass types to make them suitable as fuel stock, and typically involves biomass shredding and drying. In some cases, the power producer may also invest in a fuel collection and handling centre in the proximity of the plant for fuel storage and preparation. This processed biomass is either directly fed into a boiler to generate steam or used in a gasifier to generate producer gas, and then expanded in a turbine to generate electricity. The generated power is sold to the regional grid or a third-party.
Mitigation project continuation scenario C1	Power generation using biomass and supply to the grid continues.
Project discontinuation scenario D1	Biomass power plant is closed down. The facility may remain closed or may be adjusted to operate with coal, either with existing biomass boilers or coal specific boilers.

Source: Authors' elaboration based on interviews and analysis of project design documents.

Scenario D1 includes a number of potential eventualities for what could happen after the closure of the biomass power operation. Whether or not the facility might remain closed or may be adjusted to operate with coal is entirely dependent on local circumstances. Not only is the suitability of equipment for coal use and the available capital for adjustments relevant, but more importantly the nature of the agreement with the local electricity distribution company, and the ability to obtain new permits and power agreements for small-scale fossil fuel powered generation. It is generally understood that power purchase agreements from biomass generation are usually not easily transferable to fossil fuel powered generation, and that new agreements for such activities are often difficult or not possible to obtain. These conditions vary considerably across regions, and across individual projects. As such, scenario D1 is analysed primarily with respect to the closure of the facility, irrespective of what new economic activities might possibly follow thereafter. An analysis of different potential pathways after closure of the project would not indicate any significant variations in the conditions leading to the decision whether or not to close the project in the first place: the discontinuation scenario might lead to revenues from the resale of the equipment such as the boiler, but such revenues would always be the same regardless of whether the boiler might be sold to somewhere else or used under a new activity at the same location.

Figure 9 presents a brief overview of the processes and technologies typically involved in the plausible continuation and discontinuation scenarios for biomass IPP projects, along with a comparison to the processes of potential project discontinuation scenarios. An analysis of the conditions and feasibility of these scenarios follows in the subsequent sections.

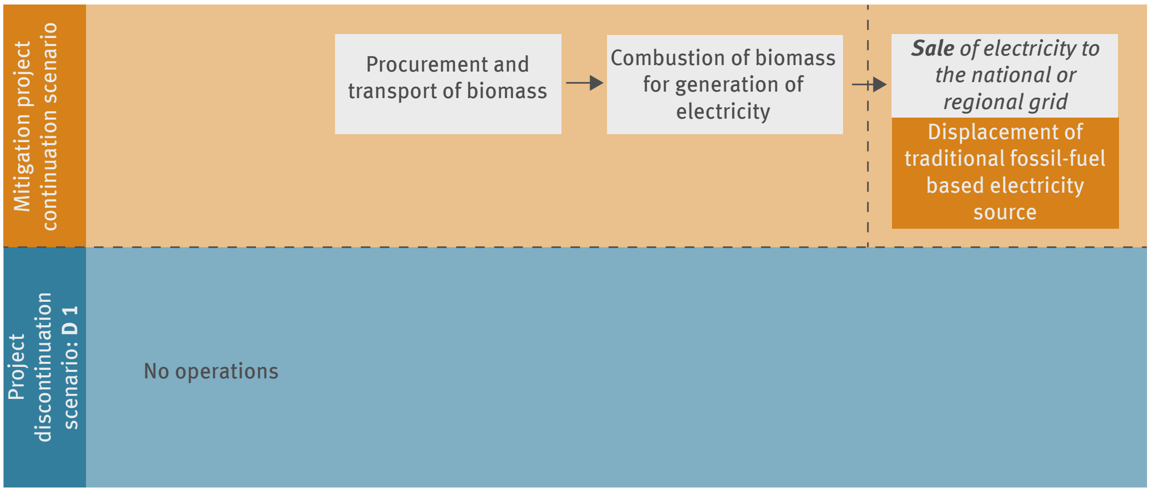


Figure 9: Overview of processes for plausible scenarios for biomass IPP projects

6.3.2 Current status of projects

Information on the current status of projects in 2014 was recorded in Warnecke et al. (2015) for at least 19 independent biomass power producer projects worldwide.

Of the 19 projects for which information could be obtained, 16 were fully implemented; 2 projects had stalled on their implementation whilst one had been implemented but was subsequently dismantled. Of the 16 implemented projects, just 8 remained in full operation. This operational rate is far below the CDM average. Approximately 75 % of projects reported that alternative revenues (e.g. from power exports) were insufficient for continuation, whilst 25 % of projects found these revenues were sufficient without CER revenues.

Information was received for 8 projects from Thailand and 6 projects from India. In Thailand five of the eight projects reported continued operation, whilst only two of the six Indian projects were operational. It is unclear to what extent the trend is significant at the country level due to the small number of projects for which information was obtained, in this instance.

6.3.3 Overview of policy landscape

Global policy efforts on biomass based power generation have focussed on regulatory obligations to mandate increased generation from renewables and policy incentives for bio-power production. Common practice approaches include targets and renewable purchase obligations for biomass based power generation and price premiums on sale of power generated from biomass. Feed-in-tariffs continue to be the most widely adopted form of renewable power support as 75 countries had these policies at the national level in 2015 (REN21, 2016). Further, policy support is targeted to small scale producers in many countries.

The current regulatory setup in India supports biomass power projects through provision of preferential tariffs for grid connected IPPs. The tariffs are set at the sub-national level. Power is procured under a long-term power purchase agreement (PPA) between distribution companies and the power producer. The government envisages an installed grid connected capacity of 10,000 MW from biomass power by 2022 under its recently revised renewable energy targets[26]. To implement these targets, mandatory renewables purchase obligations (RPOs) are set by State Electricity Regulatory Commissions (SERCs) for power distribution companies under the Electricity Act 2003 and the National Tariff Policy. RPOs differ from state to state and currently range between 2 % to 14 % of the total energy demand. Changes in the RPOs are being planned to align them with the revised national renewable energy targets. The Ministry of Power recently declared a national RPO trajectory for consultation.

26 Grid connected biomass power capacity stood at 4882.33 MW as on July 2016, according to data from Ministry of New and Renewable Energy (MNRE) website.

The national RPO trajectory notifies yearly obligation ranges of 8.75 % to 10.25 % for non-solar and 2.75 % to 6.75 % for solar for the years between 2015-16 and 2018-2019 (REConnect, 2016). In addition, some states also allow for third-part sale of renewable power through open access. The thrust of Thailand's bio power generation support has been on financial and fiscal incentives for renewable energy producers. From 2007 to 2015, premiums called 'adders' were provided over the wholesale electricity price to power producers. Adders have been replaced by feed-in-tariffs set for technology type and scale of generation in 2015, although projects generating electricity before 2013, including most CDM projects, are ineligible for transfer to the FIT programme and remain on their original VSSP adder programme tariffs (WFW, 2015). Most bio power CDM projects (and biomass projects ii general) are categorised in Thailand as Very Small Power Producers, VSPPs (up to 10 MW), which can sell up to 10 MW power to the designated distribution utility . In addition, biomass power projects are eligible to receive fiscal incentives for investment promotion. Together, these policy incentives aim to feed into the overall target for increased generation from renewables under the latest Alternate Energy Development Plan (2015-2036) of Thailand. Biomass power generation capacity is expected to contribute 5570 MW by 2036, a 56 % increase from its 2014 share.

No policy barriers exist for the continuation of the power plant with biomass as the fuel, or for the closure of the plant.

Projects in both India and Thailand are issued permits to sell electricity to the grid based on the aforementioned programmes. Whilst the sale of power to the grid through fossil fuel consumption is possible in theory, it is not possible through the existing power purchase agreements (PPA). Pursuing power generation with coal instead of biomass would require to apply for a new power purchase agreement through new channels and under a new structure, with no guarantee of success. As such, scenarios D2 and D3 – power generation continues using coal as only or major fuel – are considered for the entity of the current project activity to be incompatible with the policy landscape of India and Thailand, and are excluded from the further analysis.

Table 30: Compatibility of biomass IPP project scenarios with policy landscape in India and Brazil

Scenario	India	Thailand
C1: Power generation using biomass and supply to the grid continues.	✓	✓
D1: Power plant is closed down	✓	✓

6.3.4 Assessment of costs, financial benefits and barriers

This section includes an analysis on the financial outlook of the potential scenarios, based on the information contained in a selection of PDDs, information from the literature on current market situations, and insights from interviews with local stakeholders and experts.

Table 31 gives an overview of the types of costs and benefits incurred by biomass IPP projects, under the two remaining feasible scenarios identified. Closer analysis of these costs and benefits, along with potential barriers, is given for each scenario below the table.

Table 31: Potential costs and financial benefits for biomass IPP project scenarios

Scenario	Operation and maintenance costs					Benefits
	Biomass fuel costs	Transport of biomass	Repair/maintenance	Administration	Labour for operation	Sale of electricity
C1: Power generation using biomass continues	✓	✓	✓	✓	✓	✓
D1: Power plant is closed down						

Source: Authors' elaboration based on PDD analysis, interviews and literature

Project continuation scenario C1: Power generation using biomass and supply to the grid continues

Table 31 shows that the continuation of the independent power plant using biomass incurs costs for procurement of biomass fuel, transport of biomass fuel, labour costs for operation of the generation equipment, costs for repair and maintenance, and administration costs.

Analysis of PDDs shows that the cost of the biomass fuel is by far the most important cost; PDDs for projects in both India and Thailand estimate that biomass fuel procurement would account for around 70 % to 90 % of the total costs of the activity in 2015, although the estimated cost of the biomass was highly variable due to regional differences, as well as specific local assumptions on the supply chain.

Although biomass already accounts for the majority of the costs in PDDs, all projects in India significantly underestimated the fast growth in the price of biomass in recent years. As such, the estimations for the costs of biomass in 2015 in the PDDs for projects in India are also consistently significantly lower than the likely actual costs of biomass in 2015. Taking a general view of biomass collectively, most PDDs for Indian projects estimated costs of between INR 1,500 (~USD 22) and INR 2,000 (~USD 29) per ton of biomass. According to the official hearing of the 2015-2016 tariff determination for the Central Electricity Regulatory Committee (CERC, 2015), the price of biomass fuel for the year 2015-2016 varied between states between INR 2900 (~USD 43) and INR 3500 (~USD 52) per tonne in India (CERC, 2015). Therefore, although PDDs already identified biomass fuel procurement as the major component of their costs, this component was commonly grossly underestimated for projects in India. Information from Thailand on current prices of biomass is scarce, but the available information and local opinions indicate that the 2015 prices estimated in PDDs are a fair reflection of the current actual prices.

The only significant source of revenue for biomass IPP projects is from the sale of electricity to the grid. This is a financial component that is easier to predict, since the purchase power agreements obtained by most projects indicate specific tariff rates for several years, including up to 2020 for most projects. In India, most projects indicated a tariff per kWh in 2015 in the range of INR 4 to INR 5 (ca USD 0.06 - USD 0.08), although some projects indicated tariffs in 2015 as low as INR 2.6 (ca USD 0.04). These reflect the inter-state differences in tariffs for biomass power. In Thailand, projects indicated a tariff per kWh in 2015 in the range around THB 2.8 to THB 3.1 (ca USD 0.08 - USD 0.09).

Table 32: Operating costs and financial benefits for biomass IPP projects

Assumption on biomass price	Financial benefits* compared to operating expenditures	
	India	Thailand
According to 2015 estimation in PDDs	Greater (ca 130 %-150 %)	Greater (ca 140 %-160 %)
Actual 2015 price (lower end of range)	Equal (ca 80 %-110 %)	n.a. (PDD estimate accurate)
Actual 2015 price (upper end of range)	Lower (ca 70 %-90 %)	n.a. (PDD estimate accurate)

* Financial benefits assume constant supply of fuel and uninterrupted operation.
Finance flow data is based on the authors' calculations from analysis of a selection of twenty PDD Investment Analyses. Figures given are approximate averages from the analysed PDD documents. Data is approximate due to the small sample size, but the significance of the trends is clear.

Table 32 shows that according to the PDD-estimated biomass prices for 2015, the financial benefits of project operation should exceed the costs in India and Thailand. However, Table 32 also shows that the actual price of biomass – which is considerably higher than the estimations – means that the revenues may be equal to or significantly lower than project expenditures. Moreover, this assumes a best case scenario for the supply of biomass; that the supply is constant allowing for uninterrupted operation. In reality, the supply of biomass is reported to be a major barrier for project operation in India. The market for biomass and the supply chain remains undeveloped, relatively informal and highly unreliable. It is very difficult to arrange long-term fuel purchase agreements with reliable providers, leading to considerable fluctuations in price and availability of supply. Some power producers may be able to mitigate this barrier by stockpiling more biomass (incurring significant costs for physical space requirements) or by paying premium prices to middlemen for increased reliability. Other power producers face frequently interrupted operation. All of these cases incur additional costs of some form, and these costs are understood to be significant.

This barrier is understood to be a factor in Thailand in some cases as well, but to a lesser extent: whilst the large majority of projects in India are procuring biomass from non-associated third parties, at least half of IPP projects in Thailand are closer to the source of biomass production as they are informally associated with nearby wood chip plants or rice mills, or they produce some of the biomass themselves.

Based on the theoretical finance flows alone, conditions for the continuation scenario could be said to be *positive* in Thailand, and neutral to negative in India. Realistically, the supply chain barrier means that the conditions are *negative* for the large majority of projects in India, whilst this barrier is understood to not affect projects in Thailand as adversely. This is a generalisation for the average project situation, but the conditions of individual projects are highly variable, and the conditions for continuation may also be positive for some projects in India in the case of favourable local availability and prices of biomass

Project discontinuation scenario D1: Power plant is closed down

The closure of the power plant is a simple scenario which does not involve any activity and therefore no ongoing costs or benefits, except for possible benefits from the resale of some technological components or costs associated with plant closure (e.g. dismantling the plant). These potential benefits would be the same regardless of what pathways may be pursued following the closure of the activity, including the eventualities that the boiler would be sold for use elsewhere or sold to another operator for use at a new economic activity on the same site.

Whether or not the project might have slightly negative or slightly positive conditions for the closure of operations is entirely dependent on the conditions of individual projects. We assess this scenario as neutral (not generating any net costs or benefits) for the conditions in India and Thailand.

6.3.5 Summary of vulnerability

The analysis of potential scenarios for biomass IPP projects shows that the conclusion is variable between countries. The only feasible discontinuation scenario – *D1: closure of power plant* – results in no activities and is considered cost neutral. Therefore, the risk of project discontinuation depends solely on whether the only feasible continuation scenario – *C1: Power generation using biomass continues* – has positive or negative financial conditions.

Table 33 shows that the continuation of the project activity is understood to be an unattractive option in India, since the relatively high price of biomass makes the financial conditions of the project neutral to negative even in the case of reliable supply, whilst the supply chain barriers are also considerable, resulting in further costs. In contrast, financial conditions for project continuation with biomass are understood to be more favourable in Thailand, where biomass prices are in line with project owner’s expectations, and where supply is more reliable since many projects are formally or informally linked to the source of biomass production.

As such the risk of project discontinuation is considered to be *high* for biomass IPP projects in India and *low* for those in Thailand.

Table 33: Summary of scenarios for manure management projects

Scenario	Compatible with regulations		Financial conditions		Barriers in analysed countries
	India	Thailand	India	Thailand	
D1: Closure of power plant	✓	✓	Neutral		-
C1: Power generation using biomass continues	✓	✓	Neutral to negative	Positive	India: Highly unreliable supply chain for biomass

6.4 Biomass Used for Captive Energy Generation

6.4.1 Description of project type and scenarios

This project type includes projects that use biomass for energy generation at the site of industrial facilities, to meet the energy requirements of the facilities. This includes projects that utilise biomass for heat, those that utilise biomass for on-site electricity, and those which employ co-generation technologies for simultaneous generation of both electricity and heat.

The projects are owned by the industrial facilities in which they are integrated, they do not export electricity to the grid, and usually procure biomass from other sources. As noted in the full categorisation in Annex I, projects in the sugar, cement and palm oil industries are not included in this categorisation, as they mostly utilise biomass that is produced from within their own operations, or the operations of very closely related affiliates, and the conditions of these activities are unique.

Most of the projects use the small scale CDM methodology AMS-I.C. (Thermal energy production with or without electricity), whilst a small number use the large scale project methodologies ACM6 (Electricity and heat generation from biomass), and AM36 (Fuel switch from fossil fuels to biomass in heat generation equipment).

From the countries selected for analysis in this research undertaking, captive biomass energy generation projects are hosted mostly in India, with small numbers of projects also in Malaysia, Brazil, South Africa, Pakistan and Thailand. Overall, captive biomass energy generation projects might be hosted in up to 32 countries worldwide.[27]

In India, over 80 % of projects include the use of biomass for heating; for almost all of these projects the biomass is used in the place of coal. Approximately 45 % of projects use biomass for electricity, replacing a combination of grid electricity and diesel generator backups; these projects identify in their PDDs coal as an alternative fuel for electricity generation or cogeneration. Approximately 82 % of captive biomass energy generation projects are using rice husk as the primary biomass fuel. A further 15 % are using other agricultural residues, including soya husk, mustard husk, and jute caddies, amongst others. The remaining 3 % of projects use forest and wood based residues.

Table 34 shows that three discontinuation scenarios are identified for captive biomass energy generation projects. Not all scenarios will be possible for all projects, depending on the technologies used: the specific discontinuation scenario that may be feasible for a project depends largely upon whether the boiler installed under the project scenario is able to be operated with coal in the absence of biomass. This is discussed in further detail in the analysis of the financial conditions and barriers.

Table 34: Plausible continuation and discontinuation scenarios for captive biomass energy projects.

Project summary	***Procured biomass is utilised for on-site heat and/or electricity at industrial facilities, displacing existing or proposed fossil fuel powered alternatives.***
Process description of CDM project activity	The specific processes of the activity vary according to the specific technologies used, but can be generalised. Dedicated biomass boilers have been installed under the implementation of the CDM project, sometimes requiring significant changes to the overall heating system, and sometimes not. Biomass is procured from external sources at the appropriate season and transported to the facility, where it is stored until required. The biomass must usually be processed, for example by shredding, for feeding into the biomass boiler. The boiler generates steam which can be used to provide the heating requirements of the facility. In the case that the biomass is also used for electricity generation, existing turbines were often retrofitted under the CDM to function with higher pressure steam, or new turbines were installed. The turbines produce electricity to meet the needs of the industrial facilities. Diesel generators are normally held in reserve to maintain essential electricity services in the case of technological failure. Sometimes, existing coal or fuel oil boilers are held in reserve to maintain all essential energy services in the case of technological failure.
Mitigation project continuation scenario C1	Energy needs continue to be supplied by the use of biomass in the biomass dedicated technologies

27 The precise number of countries where these projects are found is not established under this research. Only biomass projects in the eight target countries have been investigated and re-categorised according to the project type groupings analysed for this research.

Project discontinuation scenario D1	The facility feeds coal into the boilers installed under the project activity, for meeting their energy needs.
Project discontinuation scenario D2	The facility reverts to the use of existing standby technologies that use coal and/or to electricity sourced from the national grid, for meeting their energy needs.
Project discontinuation scenario D3	The facility procures new technologies that use fossil fuels (coal, fuel oil, and/or diesel), for their energy needs.

Source: Authors' elaboration based on interviews and analysis of project design documents.

6.4.2 Current status of projects

The information in this section applies to projects that are believed to match the conditions of the target project group, as laid out in section 6.4.1.

Information on the current status of projects in 2014 was recorded in Warnecke et al. (2015) for at least 21 projects with captive biomass energy generation worldwide. Of these 21 projects, over 90 % were fully implemented with all of the remaining projects still in the process of moving towards implementation. None of the projects had been dismantled.

Of the eight projects in India for which information was obtained, all projects were implemented whilst seven of the eight projects remained in regular operation and reported that they expected to remain operational for the next 12 months.

6.4.3 Overview of policy landscape

The continuation of biomass energy projects could only be required by regulation that prohibited the consumption of specific fossil fuels at industrial facilities, regulation that prohibited the combustion of fossil fuels in boilers designed to fire biomass, or regulation that prevented the decommissioning of biomass energy generation facilities.

Neither of these potential policies exist in India. As such, all of the identified plausible scenarios are deemed to be compliant with local regulation.

The pilot ETS for air pollutants is unlikely to have a significant indirect effect on the activity, since biomass combustion may also emit air pollutants. Fewer than 20 % of captive energy projects are located in Tamil Nadu, Gujarat or Maharashtra, the three states where the ETS is piloted.

6.4.4 Assessment of costs, financial benefits and barriers

The attractiveness of the continuation and discontinuation scenarios depends largely on the cost of producing energy from biomass compared to fossil fuels. As such, an analysis into these costs is conducted, before the continuation and discontinuation scenarios are analysed further.

The costs of producing energy using biomass compared to fossil fuels

The analysis of costs and barriers is based on the analysis of PDDs as a starting point, although information is obtained from local experts and data sources to inform on the current situation for a number of important factors.

Energy generation for on-site use from fossil fuels and from biomass both incur operating costs for procuring the fuel, transporting the fuel to the facility, storage, paying wages to equipment operators, repair and maintenance of the equipment, and insurances.

Aside from the price of the different fuels, biomass fired projects are understood to incur greater costs in their operation for the following reasons:

- Biomass boilers usually require biomass material to go through a preparation process, such as shredding before being fed to the boiler.
- The physical volumes of biomass required to produce energy are far greater than the volumes of coal, fuel oil or diesel required for the same calorific output. This is due both to biomass' inferior calorific value and its lower density. This entails greater costs for transporting and storage of the biomass. Practices for reducing the transport and storage costs of biomass, such as palletisation which is widely used, for example, in Europe, are not common, so biomass is normally transported as it is or with minimal processing.
- The efficiency of biomass boilers is typically lower than for coal boilers, fuel oil boilers or diesel generators, further increasing the amount of fuel required. This entails greater costs for fuel procurement and transport.
- Biomass can include a relatively high moisture content and a large amount of inert components. This reduces the efficiency of combustion and results in more regular build-up of non-combustible waste in the boilers. High amounts of ash and non-combustible residues hinder the heat transmission within the boiler. This requires far more regular upkeep of boilers, incurring significant costs. This also increases the likelihood of machine wear or breakage, compared to coal, fuel oil and diesel based technologies, which incurs costs and may result in failure of the energy supply.
- Biomass boilers are more vulnerable to corrosion of coils and heat exchangers, leading to more regular and larger costs for maintenance and repairs.
- Biomass is often only available during specific seasons, and must be stockpiled, incurring significant opportunity costs for the large storage space requirements.

From a small selection of PDDs analysed, the costs of providing the energy needs of the facility was usually marginally more economical through the traditional fossil fuel solution than it was through the use of biomass, excluding the costs of the equipment acquisition. In most cases, the procurement of the biomass fuel was assumed to be less expensive than the calorific equivalent amount of the fossil fuel alternative, although the other incremental costs, such as the direct costs identified in the bullets above, made the final operation more expensive. These incremental costs accounted for approximately one quarter of the total operational costs of the biomass based energy, compared to less than ten per cent for most fossil fuel alternative technologies.

However, the major costs for both biomass and fossil fuel based systems are accounted for by the procurement of the fuel, usually accounting for more than three quarters of project costs, and the conditions for the continuation of projects are therefore largely dependent on current market conditions related to the prices of biomass and potential alternative fossil fuels.

Cost of biomass in India

Several sources of information exist related to the current cost of various energy generating technologies in India. Whilst there is no official database for biomass market commodity prices, reliable information may be obtained from the official hearing of the 2015-2016 tariff determination for the Central Electricity Regulatory Committee (CERC, 2015). The hearing establishes, to the best extent possible, the costs of energy generation and fuel prices, and incorporates the insights, experiences and comments from a large number of industry and supply chain stakeholders. It is therefore considered the most realistic and accurate source of information in this area.

According to CERC, the price of biomass for the year 2015-2016 varied between states between INR 2900 (~USD 43) and INR 3500 (~USD 52) per tonne (CERC, 2015). This is considerably more than the assumed biomass costs quoted in the investment documents of PDDs at the time of initial project inception, which assumed costs in the region of 1000 to 3200 per tonne (including projects registered between 2006 and 2012). At the 2015-2016 prices, energy generated with biomass would cost in the region of INR 231/GJ to INR 279/GJ, excluding incremental costs such as transport[28]. Including, as an indicative approximation, an additional INR 400 to INR 500 per tonne for transport, the cost of biomass energy could be in the region of INR 270 GJ to INR 300/GJ.

28 Range is dependent on the assumed costs and calorific values. This is based on the calorific values in Ahuja (2016).

Cost of coal in India

Global coal prices have generally fallen considerably in the past decade, from approximately USD 130 per tonne in 2008 to just over USD 40 (INR 2,800) per tonne in 2015. The cost of domestic coal in India is not entirely clear; some sources have indicated that coal might be available for between INR 1,000 (~USD 15) and INR 2,000 (~USD 29) per tonne, depending on the grade of coal, whilst indications from interviews are that the landed price of coal including transport costs could be up to INR 3,500 (~USD 53) per tonne. At the lowest prices, the price of coal per calorific value could be more than three times lower than for biomass residues in India. Even at the upper price of INR 3,500 per tonne of coal, the cost of energy would be approximately INR 167/GJ, assuming a conservative calorific value of 5,000 kcal/kg. The doubling of the coal tax rate in 2017 from INR 200 (~USD 3) to INR 400 (~USD 6) will increase the cost of coal only incrementally: assuming all other variables remain constant then the total cost of the upper range of the coal price would be approximately INR 176/GJ, still far cheaper than the average biomass cost range, unless the supply and price of biomass would be optimised to move in line with initial cost estimates from project PDDs.

Cost of fuel oil and diesel in India

Some projects use biomass as a substitute for fuel oil and/or diesel. The prices of these commodities are very similar, and have sold at approximately INR 52/l (~USD 0.77/l) throughout 2016. At this price, the cost of energy generation is far greater than for biomass or coal energy. Based on a calorific value 9,000 – 10,500 kcal/kg, the cost of energy from fuel oil in India in 2016 was in the range of approximately INR 1,225/GJ to INR 1,039/GJ.

Cost of grid electricity in India

For projects that have transitioned from grid electricity to biomass electricity, the conditions are also not favourable: CERC (CERC, 2015) indicates that the fixed and variable costs for production of electricity from biomass range from approximately INR 7.45/kWh to INR 8.92/kWh (~USD 0.11 – 0.13 /kWh) depending on the specific technology and the region. This is slightly greater than the price of grid electricity for industrial users in India in 2016, which ranged between states from around INR 6/kWh to INR 8/kWh[29] (~USD 0.9 – 0.12 /kWh).

It is clear from this information that the price of coal is lower than that of biomass, marginally in the case of the highest coal prices and many times over in the case of the lowest possible coal prices. Grid electricity is also likely to be cheaper than electricity generated using biomass. The only fuel which is more expensive than biomass in terms of cost per calorific value, is fuel oil and diesel.

Comparison of project continuation and discontinuation scenarios

Since the project activity relates only to one part of the wider economic activity (energy supply for wider industrial processes), all of the identified continuation and discontinuation scenarios entail the continuation of the situation that energy will be supplied, but focus on the optimisation of this process. Since the different continuation and discontinuation scenarios refer to an optimisation of one process rather than broader options, it is not logical to discuss their economic conditions in terms of negative, neutral or positive conditions; in the situation where the supply of energy is a constant requirement in all scenarios for the broader project activity, the financial costs of all scenarios should be considered negative, since any of the forms of energy supply entail costs. Rather, their economic conditions should be compared to each other directly, in order to determine which is the least-cost option.

The previous section indicated that the price of coal in India in the present market condition makes it a lower-cost option for projects than the use of biomass, fuel oil, diesel or grid power, for heating and electricity. This information alone would suggest that the use of coal fed into the boilers installed under the project activity – ***discontinuation scenario D1*** – or the use of coal fed into existing standby boilers – ***discontinuation scenario D2*** – are scenarios that are more attractive than the continued use of biomass – ***continuation scenario C1*** – if technically feasible, since it entails no costs for reverting to the cheaper alternative fuel. However, these scenarios also entail barriers in some cases:

29 Price information based on actual prices offered to industrial users in 2015, obtained from interviews.

Discontinuation scenario D2 does not entail barriers as such, except that not all projects have existing standby boilers, either because the boilers used under the previous activity were sold or decommissioned, the industrial operation and associated energy demand was new at the time of project inception and no old boilers existed, or because old boilers were retrofitted under the project.

Discontinuation scenario D1 entails barriers regarding the suitability of the biomass boilers to accept coal:

- In some cases, the technology of the biomass boiler may be entirely incompatible with the use of coal as a fuel. This is understood to be a relatively uncommon case. Furthermore, the analysis of PDDs indicates that there are very rarely cases where this barrier prevails in parallel with the potential barrier for D2 (the absence of backup boilers). Most projects operate with boilers that can be fed with coal in the case that biomass supply is not available or economical, and those that do not usually maintain old coal-fired boilers on standby.
- Although it is possible to feed coal into most small scale biomass boilers in theory, this does involve some complications which equate to efficiency losses in most cases, since the grates of these boilers are often designed and optimised for a specific volume and form of fuel, which differs to that of coal. The efficiency losses depend on the specific boiler and are significant in some cases whilst marginal in others; these efficiency losses increase the cost of producing energy in a biomass boiler with coal, to the extent that the cost of coal with such technology may be comparable with the cost of biomass. The huge variability of project conditions regarding the specific boiler technology and the landing price of fuels means that coal could be a far more economical option, or it could be comparable with biomass.

Continuation scenario C1 also faces a major barrier beyond considerations on the price of the fuels. The use of biomass for on-site energy faces a significant supply chain barrier. The supply chain for biomass is highly variable according to local conditions but is, in most cases, informal and erratic. Energy security from biomass is very poor on the long-term due to the uncertainty of the market but also at the short- and immediate term due to the informality of the market and the relative unreliability of suppliers. There is no steady supply of biomass, nor a steady cost. This barrier represents a major risk for industrial facilities, for whom energy security is paramount to continued production, which is the major line of business. Several studies have identified that the security of fuel is a more important factor than the simple economics of the fuel price for industrial energy users (Asian Institute of Technology, 2005; Evald, 2005).

For the small number of projects where barriers prevent both scenario D1 and scenario D2, **the procurements of new coal fired boilers – discontinuation scenario D3** – may be an alternative. Whilst regular operation under such a scenario is likely cheaper than the continued use of biomass, the scenario entails a considerable barrier in the upfront capital required for the procurement of the new boiler. Whether or not this scenario is economically attractive option compared to the continued use of biomass is entirely circumstantial and variable across projects: factors include the amount of capital available for energy related investments, local market conditions and potential agreements with biomass and fossil fuel suppliers. The small number of projects for which scenario D3 is a relevant option due to barriers to both scenarios D1 and D2, and the variability of the conditions of these projects, means that it is not possible to speculate on general trends regarding whether or not discontinuation scenario D3 is a more economically attractive option to scenario C1.

6.4.5 Summary of vulnerability

The analysis of scenarios indicates that the discontinuation scenarios are the most likely for captive biomass energy projects. Table 35 shows that discontinuation scenario D2 and D3 are the most cost effective means of producing power. Scenario D3 is considered unlikely to the high upfront cost of capital investments, whilst scenario D2 may not be a feasible option if no backup boilers exist.

Between scenario D1 and scenario C1, D1 is considered the more likely scenario. Although the ongoing energy generation costs may not necessarily be significantly more favourable for scenario D1 in all cases, the biomass supply chain barrier associated with scenario C1 is a major issue for projects integrated into industry.

As such the risk of discontinuation for biomass captive energy projects in India is considered to be generally high, with projects likely to revert to the use of existing standby technologies – ***scenario D2*** – where such boilers are available, and the use of coal in the biomass boilers – ***scenario D1*** – in other cases.

Table 35: Summary of assessment of biomass captive energy projects in India

<table>
<tr><th>Scenario</th><th>Regulatory compliance</th><th>Energy generation costs</th><th>Barriers</th></tr>
<tr><td>D2: The facility reverts to the use of existing standby technologies that use coal and/or to electricity sourced from the national grid, for their energy needs.</td><td>✓</td><td>This scenario is considered the least cost option for ongoing energy generation.</td><td>▸ Standby boilers may not exist. This usually only applies to projects where scenario D1 is feasible, and where backup boilers are therefore not needed.</td></tr>
<tr><td>D3: The facility procures new coal fired boilers for their energy needs.</td><td>✓</td><td>Ongoing generation costs are likely to be lower than for inefficient use of coal (D1) or biomass (C1).</td><td>▸ Upfront capital for new boilers is likely to be prohibitive.</td></tr>
<tr><td>D1: The facility feeds coal into the boilers installed under the project activity, for their energy needs.</td><td>✓</td><td rowspan="2">These scenarios are considered higher cost options for ongoing energy generation. Depending on the technology and the efficiency of the biomass boiler with coal, these scenarios may be comparable, or D1 may be considerably lower cost than C1.</td><td>▸ Boiler design may not accept the use of coal. Known to affect a minority of projects.</td></tr>
<tr><td>C1: Energy needs continue to be supplied by the use of biomass in the biomass dedicated technologies</td><td>✓</td><td>▸ Security of fuel supply is very poor due to immature and volatile market.</td></tr>
</table>

6.5 Summary of Vulnerability for Biomass Energy Projects

Table 36 summarises the conditions for biomass energy projects. Biomass energy projects have demonstrated considerable variability according to the specific conditions of individual projects. The conclusions presented here are generalisations whilst the conditions of individual projects may be rather different. Whilst this is true for all project types, the variability amongst biomass energy projects was notably greater.

- Bagasse energy in the sugar industry is a low risk activity in both India and Brazil due to the highly positive economic conditions from the sale of electricity to the grid.
- Biomass IPP projects are generally at high risk of discontinuation in India, where biomass prices are relatively high and the biomass supply chain is unreliable. The risk of projects in Thailand is comparatively lower, due to more favourable conditions for the price and availability of biomass for projects.
- Projects using biomass for captive energy generation in India are generally considered to have a high risk of discontinuation, since the price of biomass as well as the unreliability of the supply chain favour a switch to coal fired energy generation in most cases.

Table 36: Summary of vulnerability of biomass energy projects

	India	Brazil	Thailand
Bagasse energy in sugar industry	Low risk	Low risk	Not evaluated
Biomass IPP	High risk	Not evaluated	Low risk
Biomass for captive energy	High risk	Not evaluated	Not evaluated

7 Household Energy Efficiency – Assessment of Project Discontinuation Risk

7.1 Overview of project type and identification of groupings for analysis

Following an initial review of the UNEP DTU project type classifications, presented in full in Annex I, two major and distinct project groupings were identified and selected for further analysis under the household energy efficiency project type:

- **Lighting (including methodologies AMS-II.C. & AMS-II.J.)**
  Energy-efficient lighting projects account for the bulk of projects (163) and for 62 % of expected emission reductions among household energy efficiency CDM projects. The two main methodologies refer to new energy-efficient equipment in general (AMS-II.C.) and more specifically to energy-efficient light bulbs (AMS-II.J.). The methodologies are similar in a way that both consider the reduction of electricity consumption and corresponding GHG emissions as the main outcome of the projects. An analysis of projects with these two methodologies is carried out collectively.
- **Cook stoves (including methodologies AMS-I.E. & AMS-II.G.)**
  The second-largest project type among household energy efficiency projects are cook stove projects accounting for 51 projects and for 21 % of expected emission reductions up to 2020 amongst household energy efficiency CDM projects. The two methodologies refer to switch from non-renewable biomass for thermal applications by the user (AMS-I.E.) and to energy efficiency measures in thermal applications of non-renewable biomass (AMS-II.G.). The methodologies are similar in a way that both consider the reduction of the use of non-renewable biomass and corresponding GHG emissions as the main outcome of the projects. However, there are also some differences, as under AMS-II.G more efficient stoves are used, while under AMS-I.E usually stoves are replaced, e.g. by solar cookers. Solar cookers, which are likely used in parallel to another cooker, may have different conditions for continued use than improved stoves.

Table 37 provides an overview of how the project types are allocated among the selected countries.

Table 37: Overview of the distribution of household energy efficiency project type across countries

Country	Lighting AMS-II.C. AMS-II.J.	Stoves AMS-I.E. AMS-II.G.
India	**80**	**31**
Thailand	0	0
Malaysia	0	0
Pakistan	**53**	0
Mexico	**25**	1
Brazil	0	0
South Africa	3	2
Kenya	1	**17**

Based on the information in Table 37, household energy efficiency projects will be analysed with regard to the following two project groups:

1. *Lighting* projects with methodologies AMS-II.C. & AMS-II.J., with a focus on India, Pakistan and Mexico.
2. *Stoves* with methodologies AMS-I.E. & AMS-II.G., with a focus on India and Kenya.

7.2 Lighting Projects

7.2.1 Description of project type and methodology

For the purpose of this analysis, the lighting projects of interest are those classified under EE households by the UNEP DTU pipeline. CDM methodologies for these lighting projects include both new energy-efficient equipment in general (e.g. lamps, refrigerators, motors, fans, air conditioners, pumping stations and chillers) (AMS-II.C.) and more specifically energy-efficient light bulbs (AMS-II.J.). Both methodologies refer to small-scale projects and can include the same type of activities, with the main difference being the broader scope of AMS-II.C in terms of both eligible technologies (i.e. beyond energy efficient lighting only) and sectors (i.e. beyond residential only). Projects registered under both methodologies are therefore analysed if they refer to household lighting.

From the countries selected for analysis in this research project, household energy efficient projects with a focus on the replacement of inefficient lightbulbs are particularly prominent in India, Pakistan and Mexico. Outside of the selected countries, household lighting projects also take place in Bangladesh, China and South Africa. The technology employed is very similar for all small-scale projects. The technology and abatement methodology is summarised, alongside plausible continuation and discontinuation scenarios, in Table 38 below.

Table 38: Plausible continuation and discontinuation scenarios for household lighting projects[30]

Project summary	***Replacement of more GHG-intensive lighting by a technology switch in households (subsidised by the project developer) to more efficient alternatives (i.e. CFLs and LEDs)***
Process description of CDM project activity	Efficient light bulbs (e.g. compact florescent lamps (CFLs) and light emitting diodes (LEDs)) are distributed to consumers (i.e. possibly through an organisation such as an energy utility company) within a defined geographic area at a comparable price to that of an incandescent lamp (ICL). The consumers need to exchange their current less energy efficient ICLs (i.e. higher wattage, equivalent luminosity) for more energy efficient lightbulbs. To discourage free-riding householders may also need to pay towards the cost of the CFL/LED (albeit a fraction of the retail price). The ICLs are subsequently collected by the project developer and destroyed (after an appropriate inspection). The project developer is also responsible for regular maintenance (i.e. the project developer is obligated to replace defective CFLs/LEDs under a warranty program) as well as for outreach activities.[26]
Project continuation scenario C1	The efficient lightbulb continues to be used as long as it is working. Once the efficient lightbulb is broken, a new efficient lightbulb is bought at the expense of the CDM project owner.
Project continuation scenario C2	The efficient lightbulb continues to be used as long as it is working. Once the efficient lightbulb is broken, a new efficient lightbulb is bought at the expense of the household.
Project discontinuation scenario D1	The newly installed efficient lightbulb continues to be used by the household until a defect occurs, at which point a cheaper, less efficient ICL is purchased as a replacement.
Project discontinuation scenario D2	The householder sells the more efficient lightbulb and replaces it with a cheaper inefficient lightbulb

Source: Authors' elaboration based on interviews and analysis of project design documents.

Figure 10 presents an initial overview of the technology, processes and financial implications typically involved in the project continuation and discontinuation scenarios for household lighting projects.

30 The CDM project scenario focuses only on household energy efficiency projects, which replaces inefficient lightbulbs as this represents the majority of household lighting projects for Mexico, India and Pakistan in the UNEP DTU Pipeline as of January 2016.

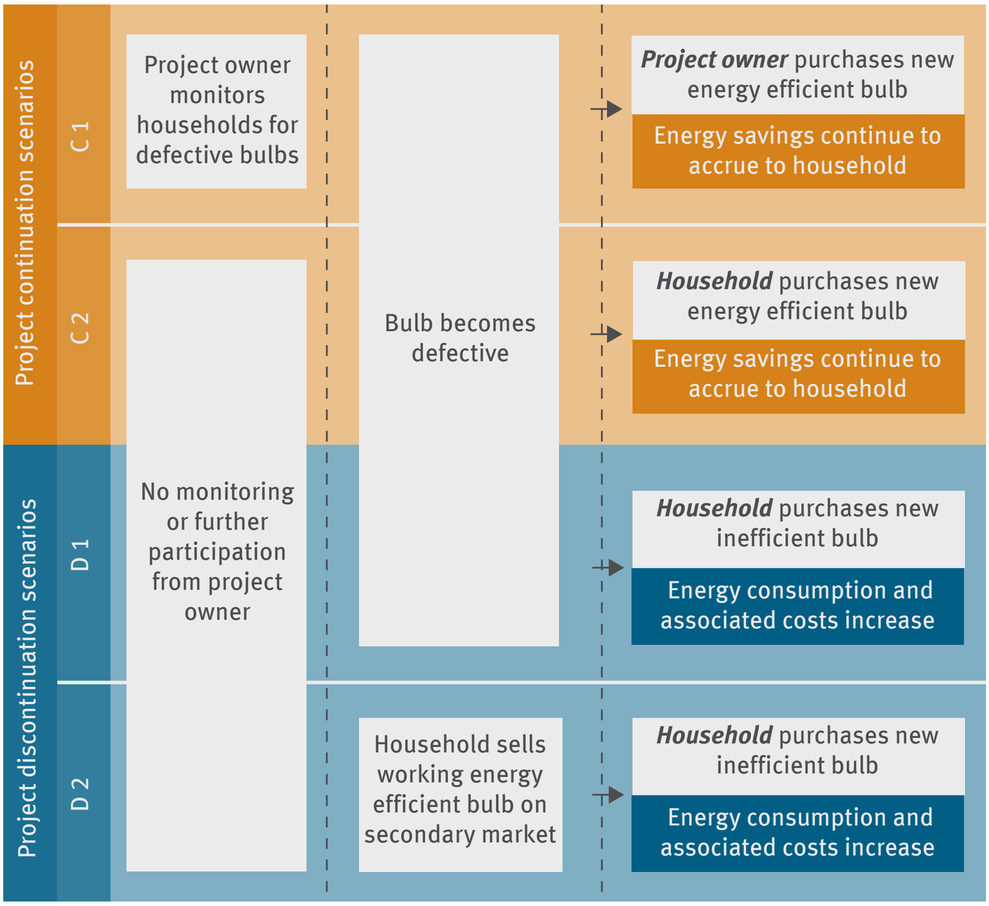


Figure 10: Overview of processes for household lighting projects

7.2.2 Current status of projects

In research by Warnecke et al (2015), 34 projects for household lighting were randomly selected for evaluation, including 14 projects in India and 1 project in Mexico. Overall, household lighting projects demonstrate a low rate of project implementation at 52 %. A high proportion of household energy efficiency projects are projects with a registration date in 2012 and/or PoAs, and a number of projects are therefore still in the planning and implementation phases. However, there are also a number of projects being discontinued and dismantled, even amongst the 2012 registrations.

Pakistan was not included as a focus country in Warnecke et al (2015), so the precise status of these projects in not known. As of yet, the National CFL Project in Pakistan, which consists of 53 registered CPAs, has not issued any CERs (UNEP DTU, 2016).

7.2.3 Overview of policy landscape

Conditions for the continuation of household lighting projects in the absence of CER revenues may be heavily influenced by local policy. The most influential type of legislation, in this regard, would be legislation that explicitly requires the continuation of the activity:

- Such regulation might involve the phasing out of the use of inefficient lightbulbs (i.e. ICLs) by banning the sale of such products within the host country at a certain point in time.
- The setting of minimum efficiency standards for lighting would also lead to the replacement of inefficient lightbulbs with more efficient lightbulbs if the standard is higher than the energy efficiency (i.e. lumen per watt output) associated with ICLs. These standards could also coincide with an efficiency labelling scheme to provide the consumer with more information about their purchase decisions.
- The provision of subsidies or tax incentives to encourage the purchase of more energy efficient lighting would likely result in households replacing their current inefficient lighting if the host country government had sufficient resources available.

- In addition, policies that improve awareness of the financial benefits of energy efficiency to the consumer (i.e. energy efficient labelling schemes / promotional campaigns) would also be of benefit here.

An assessment of policies and measures in India, Pakistan and Mexico found that legislation is in place to support the uptake of more energy efficient lighting in households (in the absence of CER revenues), albeit the levels of policy ambition and the degree of implementation and enforcement varies amongst the three countries with currently the largest share of CDM projects in household energy efficient lighting.

- *India* does not yet have a ban on incandescent bulbs; however, the production of ICLs of 150 watts and above has been stopped. The manufacture of 500 and 1000 watt halogen lamps has also been ended with the introduction instead of more environmentally friendly eco halogen lamps of 400 and 750 watts (TERI, 2014). According to UNEP (2016a), there is the potential to ban ICLs.

  India currently has mandatory minimum energy performance standards for CFLs under the standard IS-15111. The standard covers the range of capacities and efficacy of CFLs. CFLs from 8 to 10 watts need to have 50 lm/W*, CFLs from 11 to 15 watts need to have 55 lm/W, 16 to 23 watt lamps need to have 60 lm/W* and 24 to 26 watt types need to have 60 lm/W (UNEP, 2016). India has voluntary minimum energy performance standards for fluorescent lamps and has adopted IEC performance standards for LEDs' (TERI, 2014). India also has 'mandatory labelling for tubular fluorescent lamps. The labelling programme for these products was launched in 2006 and became mandatory in 2010. To date, 46 fluorescent lamp types have been approved for star rating. The labelling system uses comparative labelling which varies from one star to five stars, depending upon the hours of usage and luminous efficacy (lm/W)' (TERI, 2014).

  Several domestic energy efficiency funds (i.e. State Energy Conservation Fund (SECF), Partial Risk Guarantee Fund (PRGF) and Venture Capital Fund for Energy Efficiency (VCFEE)) as well as utility programmes (i.e. instalment payments through electricity payments established by BELP utility company) have also been implemented in India to promote energy efficient lighting in the country (UNEP, 2016).

  These policies and measures have contributed to a rapid transformation of efficient lighting during the last decade in India with sales of CFLs increasing from 7.8 % of total lighting requirements in 2005 to 37 % in 2014 (Government of India, 2015). The uptake of efficient lighting in the country is set to improve further following the announcement of an ambitious plan by the Indian government to replace all ICLs with LEDs over the next few years (India, 2016).

  The Domestic Efficient Lighting Programme (DELP) is led by Energy Efficiency Services Ltd (EESL), which is a joint venture between several state-owned utility firms. Under the programme, the government procures large volumes of LED lightbulbs through the EESL (via a competitive bidding process) and then distributes them to consumers at discounted rates with the upfront costs financed by EESL (recovered through the financial savings on electricity bills). The programme has been a 'game changer' for India's lighting market. The stable, large scale demand for LEDs has encouraged the build-up of domestic production, which has led to a fall in the wholesale price of an LED bulb from more than INR 300 ($4.8) at the start of 2014 to INR 70 ($1.1) in mid 2015 (IEA, 2015b).
- In *Pakistan*, 'minimum energy performance standards for CFLs' have been established and voluntarily followed.[31] Pakistan's minimum energy performance standards still allow incandescent bulbs.

  An energy efficiency standards and labelling policy and programme has been adopted and when fully operational will contribute to the reduction of energy consumption from lighting with any product that meets the minimum energy performance standards classified under the labelling scheme. The government has also provided tax exemptions on imported CFLs, and LED lighting fixtures to encourage consumers to switch to more efficient technologies (TERI, 2014). Furthermore, the Pakistan government is likely to include financial incentives for LED lightbulbs (i.e. concessions of customs duty on local manufacturing of LED lights) in the 2016-2017 Budget (Abrar, 2016). In the absence of implemented standards for ICLs, such subsidies are important to influence consumer behaviour.

31 The standards referred to for developing the minimum energy performance standards are PS IEC 60969. PSQCA is the agency responsible for the development and approval of standards, whereas ENERCON is the responsible agency for implementation of the programme.

Within Pakistan energy efficient lighting awareness campaigns have been introduced as well as funds for energy-efficiency (i.e. National Energy Conservation Fund (ECF) were established as part of UNDP/GEF-funded FERTS project and Asian Development Bank (ADB) funding for energy-efficiency investments) (UNEP, 2016).

Pakistan is classified at the same level as India in the policy assessment undertaken by the UNEP (2016) Enlighten Initiative as the country has also made considerable efforts to promote household energy efficiency improvements.

- *Mexico* has in effect, through the introduction of minimum energy performance standards, forbidden the commercialization of ICLs for 100 W in December 2011, for 75 W in December 2012 and for 60 W and 40 W in December 2014 (Valdez, 2015). This implies that even without CER revenues, there would be no switch-back to ICLs.

  Mexico has also established energy efficiency labelling under the Electrical Power Saving Trust Fund (FIDE) label, which covers products that have met specified standards and identifies it as a FIDE certified energy efficient product. Lighting products included under the scheme are lamps, ballasts and luminaries (IEA energy efficiency policy database, 2016). Mexico further provides financial support to consumers under the Programme for Financing of Electric Energy Saving (PFAEE). The cost of more efficient lighting is financed through a credit paid on electricity bills, which is largely recovered due to reduced electricity costs (IEA, 2016).

  Given the introduction of ambitious minimum energy performance standards for lighting in Mexico, which have essentially forbidden the use ICLs, it is likely that the use of efficient lamps will continue even in the absence of CER revenues. Indeed, financial measures further support consumers in Mexico to switch from inefficient to more efficient lightbulbs.

  In summary, as shown in Table 39, the regulations in India, Pakistan and Mexico are all compatible with continuation scenario; however, the stricter regulation in Mexico to prevent the use of ICLs is not compatible with the discontinuation scenarios considered in this study.

Table 39: Regulations for lighting in India, Pakistan and Mexico

Scenario	Compatibility of scenarios with regulations		
	India	Pakistan	Mexico
C1: CFL/LED continues to be used and once broken replaced with an efficient lightbulb by the CDM project developer.	✓	✓	✓
C2: CFL/LED continues to be used and once broken replaced with an efficient lightbulb by the household.	✓	✓	✓
D1: CFL/LED continues to be used by the householder but once broken replaced with an inefficient lightbulb.	✓	✓	×
D2: CFL/LED not used but sold and replaced with an inefficient lightbulb.	✓	✓	×

7.2.4 Assessment of costs, financial benefits and barriers

In addition to information and insights from local experts, several projects from different countries were selected for analysis of financial conditions, as included in, or attached to, their PDDs. The analysis shows the division of the costs and benefits of installing energy efficient lighting between both the project developer and the householder. In this subsection the costs and benefits of each of the scenarios are analysed. Costs are considered in terms of the subsidy provided by the project developer to the householder for efficient lightbulbs as well as ongoing operating expenditures and maintenance completed by the project developer. Householders primarily benefit from the installation of energy efficient lighting via the reduction in electricity consumption and therefore costs.
Table 40 gives an overview of the types of costs and benefits incurred by lighting projects, under the scenarios identified. Closer analysis of these costs and benefits, along with potential barriers, is given for each scenario below the table.

Table 40: Potential costs and financial benefits for energy efficient lighting project scenarios

Scenario	Operation and maintenance costs			Benefits	
	Monitoring house-holds (PD)	Replacement of EE lightbulbs (PD)	Replacement of EE lightbulbs (HH)	Cost savings from reduced electricity use (HH)	Sale of working EE lightbulbs (HH)
C1: CFL/ LED continues to be used and once broken replaced with an efficient lightbulb by the CDM project developer.	✓	✓		✓	
C2: CFL/ LED continues to be used and once broken replaced with an efficient lightbulb by the household.			✓	✓	
D1: CFL/ LED continues to be used by the householder but once broken replaced with an inefficient lightbulb.					
D2: CFL/ LED not used but sold on the secondary market and replaced with an inefficient lightbulb.					✓

Note: It is assumed that benefits accruing to the project developer only stem from CER sales. Some projects may be operated by ESCOs and therefore have additional financial benefits over those analysed in this document, and even better prospects for continuation, but it is understood that these only reflect a very small number of CDM projects.

Source: Authors' elaboration based on PDD analysis, interviews and literature. PD refers to project owners/administrators; HH refers to households.

Project continuation scenario C1: CFL/LED continues to be used and once broken replaced with an efficient lightbulb by the CDM project developer

In order to assess the financial benefits and operating expenditures associated with household lighting projects, a selection of PDDs were reviewed under the AMS-II.J methodology in both India and Pakistan and under the AMS-II.C methodology in Mexico.

In general, household lighting projects involve the consumer receiving a more efficient lightbulb to replace an inefficient lightbulb. These lightbulbs are subsidised by the project developer and are normally distributed for free or at a minimal cost to gain buy in from the user, so that the equipment is actually valued/used. The consumer benefits from lower electricity costs without having to pay a higher initial cost for the product. However, it is important to acknowledge that CFL costs have declined in recent times. Indeed, an individual CFL (11 W) can currently be purchased in India for around US$ 1.5,[32] which reduces the capital cost barrier to the adoption by households of more efficient lighting. The costs of LED lightbulbs have also declined (refer to Section 7.2.3).

Based upon the responses from interviews conducted for the study with project developers involved in lighting projects, it is very unlikely that broken efficient lightbulbs will be replaced by project developers in the absence of CER revenues. The financial conditions for scenario C1 are therefore deemed highly negative since the project developer would incur continued costs with no financial benefits (which are accrued to the household). Despite this general conclusion it should be noted that in a handful of cases C1 might be viable if the project owner (i.e. an NGO) is motivated by non-financial incentives such as research or community development.

Project continuation scenario C2: CFL/LED continues to be used and once broken replaced with an efficient lightbulb by the household

Financial conditions are clearly positive for households since their energy savings will easily offset the payments for the more expensive light bulbs, over a longer period of time. The table below provides a comparison between the typical characteristics and costs of LEDs, CFLs and halogens (ICLs).

32 Based on the purchase of a Khaitan 11 W CFL Combo of 2 for 190 Rs. Converted from Rs to US$ (based on the conversion rate of 1 Rs = 0.015 US $) and divided by two. Refer to (https://paytm.com/shop/g/home-kitchen/led-cfl-bulbs/cfl accessed on 20th of July 2016).

Despite the higher purchase prices of both LEDs and CFLs it is still expected that reduced electricity costs would exceed the higher initial purchase costs over the lifetime of the LED / CFL (in comparison to the use of a ICL). As the share of energy efficient lighting in domestic markets increases, the upfront costs associated with efficient lighting will continue to fall. Indeed, the 2015 World Energy Outlook estimates that the costs of CFL and LED lighting could decrease by 47-55 % between 2014 and 2030 for the same level of lighting (IEA, 2015c). The increasing competition between CFLs and LEDs will also help to drive down the price of efficient lighting. Furthermore, government policies have also improved the ability of households to purchase efficient lighting (see previous sub-section on applicable laws and regulations).

Table 41: Cost per lamp: LEDs compared with CFLs and halogens (ICLs)

	LED	CFL	Halogen (ICL)
Watts (equivalent lamps)	6	11	35
Purchase price per lamp (GBP)	6.00	3.50	2.00
Typical annual lamp use (hours)	1,000	1,000	1,000
Typical lamp lifetime (hours)	30,000	10,000	2,000
Typical lamp lifetime (years)	30	10	2
Cost of lamp purchases over 30,000 hours / 30 years (GBP)	6.00	10.50	30.00
Annual energy consumpti-on per lamp (kW)	6	11	35
Annual electricity cost per lamp at 14.95/kW (GBP)	0.84	1.55	4.92
Total cost per lamp per year averaged over a typical LED lamp life – 30 years (GBP)	1.04 per year	1.90 per year	5.92 per year

Source: Energy Saving Trust (2016)

The financial conditions for scenario C2 are deemed to be positive, since the energy savings of the efficient light-bulbs can far offset the costs within a reasonable timeframe. However, efficient lighting projects are subject to the problem of divided (split) incentives. While the owner of the project pays for the installation of the clean cook stoves, it is the householder normally who accrues the direct benefits from any electricity savings. The continuation of these projects under scenario C2 is subject to significant barriers:

- Affordability of the renewed investment for households
- Lack of understanding and knowledge on the benefits of energy efficient bulbs

Lack of access to capital remains the main barrier to the adoption of energy efficient lighting in poorer house-holds. All of the PDDs reviewed in this study for lighting CDM projects in India used the investment barrier in order to demonstrate additionality. The PoA 'National CFL Project' in Pakistan and the 'Smart Use of Energy' PoA in Mexico also completed an investment analysis and referred to the upfront capital requirements towards the purchase of CFLs as the key barrier to the uptake of the project. The lack of understanding and knowledge on the benefits of energy efficient bulbs were also regularly cited in these PDDs as an important additional barrier.

To overcome this key barrier, lighting projects were originally set up to provide a financial subsidy to househol-ders to enable them to experience the financial benefits of lower electricity bills.

Projects were often accompanied with outreach activities to explain the benefits of using more efficient lighting in order to overcome the additional barrier of information failure (i.e. barriers here include time lag between energy consumption and payment of bills / aggregated energy prices may limit householders' understanding of individual appliance use). Indeed, the awareness raised during the initial distribution of CFLs is likely to have educated many households on the financial benefits of efficient lighting despite the higher capital costs (compared to inefficient lighting).

However, with the costs of the technology declining and the market penetration of efficient lightbulbs increasing (due in part to government policies) it is evident that the previous barriers to efficient lighting are nevertheless being overcome in Mexico, India and Pakistan. Given the increasing market penetration of CFLs and LEDs at the expense of ICLs (UNEP, 2016) it is increasingly unlikely that households will replace failed CFLs with less efficient lighting.

Project discontinuation scenarios

Financial benefits may theoretically be accrued through the re-sale of the CFLs/ LEDs on the market, but this potential is rather limited. The potential resale value of CFLs / LEDs is low with any attempt to recover the original capital expenditure undermined by the high transaction associated with any sale (i.e. collection of the CLFs/ LEDs, identification of a buyer in a limited market for used equipment). Furthermore, in doing so, the household forgoes the more significant benefit of energy cost savings. It is therefore considered that the financial conditions for scenario D2 (CFL/ LED not used but sold on the secondary market and re-placed with an inefficient lightbulb) are negative, and only likely under specific circumstances: the re-sale of the CFLs/ LEDs may occur depending upon the wealth of the household (i.e. low discount rate) and the impact of outreach activities to educate householders on the financial benefits of efficient lighting.

As the market share of efficient lighting increases, the extent to which households will revert to inefficient lightbulbs after the failure of a more efficient lightbulb becomes less likely as upfront costs continue to decline (refer to section on the continuation scenarios for C1 and C2).

7.2.5 Summary of vulnerability and scenarios for energy efficient lighting projects

Table 42 gives a summary for the potential scenarios for lighting projects in order of their financial attractiveness regarding the ongoing costs and benefits. The information in financial conditions relates only to ongoing financial flows and does not include upfront capital expenditures. Compatibility with regulations and other barriers are included in the table to help identify the most likely scenario for continuation.

Table 42 shows that continuation scenario C2 (renewed investment in energy efficient lightbulbs by households) is the financially most attractive scenario, but marred by barriers. In the case that the barriers are insurmountable, a discontinuation scenario is considered to be the next likely scenario in India and Pakistan. In Mexico, the discontinuation scenario is not a possibility due to regulation. The analysis in this study, based on a range of sources and local insights, concludes that the barriers for scenario C2, although significant, are increasingly being overcome, and not likely to prevent the scenario in the majority of cases.

Table 42: Summary of the assessment of lighting project scenarios

Scenario	Compatible with regulations	Financial conditions	Barriers and mitigating factors in analysed countries
C2: CFL /LED continues to be used by the householder and replaced with an efficient lightbulb by the householder.	✓	Positive	Affordability up upfront costs for households and knowledge of benefits
D1: CFL /LED continues to be used by the householder but replaced with an inefficient lightbulb.	✓ (India, Pakistan) × (Mexico)	Neutral/negative	-
D2: CFL/ LED not used but sold and replaced with an inefficient lightbulb.	✓ (India, Pakistan) × (Mexico)	Negative	Potentially still possible in the case that knowledge on benefits is lacking
C1: CFL/ LED continues to be used by the householder and replaced with an efficient lightbulb by the CDM project developer.	✓	Very negative	Mitigating factor: Project developer might be motivated by non-financial incentives and may continue in this case.

To summarise, efficient lightbulbs are likely to be used by the householder as long as energy savings reduce electricity costs. The increasing market penetration of energy efficient lighting in all three countries indicates that householders are aware of the financial benefits and will consequently continue to use more efficient lighting. Interviews with project developers of lighting projects in India have supported this claim, although consumer patterns may continue to vary on a case by case basis depending upon different factors. Given the policies currently in place in many countries, the reduction in CFL/ LED costs and the lifetime of CFLs /LEDs compared to a fixed crediting period – household energy efficient lighting projects are deemed to have low vulnerability, and it is unlikely in practice that further support will be required for the continuation of the use of the equipment.

7.3 Cook Stoves

7.3.1 Description of project type and methodology

For the purpose of this analysis, the cook stove projects of interest are those classified under EE households by the UNEP DTU pipeline. CDM methodologies for these cook stove projects include a methodology for replacing cook stoves using non-renewable biomass by alternative renewable energy technologies such as solar or biogas cookers (AMS-I.E) and a methodology for using more energy efficiency cook stoves (AMS-II.G). The methodologies are similar in a way that both consider the reduction of the use of non-renewable biomass and corresponding GHG emissions as the main outcome of the projects. From the countries selected for analysis in this research undertaking, cook stove projects are particularly prominent in India and Kenya. Among the selected countries, cook stove projects also take place in South Africa and Mexico. The technology employed is very similar for all projects. The technology and abatement methodology is summarised in Table 43 with plausible continuation and discontinuation scenarios.

Table 43: Plausible continuation and discontinuation scenarios for household cook stove projects

Project summary	***Traditional inefficient cook stoves are replaced at the household level by more efficient cook stoves or by alternative renewable energy solutions.***
Process description of CDM project activity	Improved cook stoves (with a thermal efficiency of around 30 %) or alternative renewable energy solutions (i.e. solar cookers) replace inefficient traditional cook stoves (with a thermal efficiency of only around 10 %), which are also associated with greater health risks caused by indoor air pollution. The householder will benefit from energy savings due to lower fuel consumption of non-renewable biomass through either minimising thermal energy losses with improved cook stoves or by adopting alternative renewable energy solutions. Householders receiving newly installed clean cook stoves are normally selected based on greatest need by an organisation affiliated with the host country.
Project continuation scenario C1	The newly installed clean cook stove continues to be used as long as it is working. Once the newly installed clean cook stove is broken, a similar new cook stove is bought at the expense of the CDM project owner.
Project continuation scenario C2	The newly installed clean cook stove continues to be used as long as it is working. Once the newly installed clean cook stove is broken, a similar cook stove is bought at the expense of the household.
Project discontinuation scenario D1	The newly installed clean cook stove continues to be used by the household until a defect occurs, at which point a traditional cook stove is used as a replacement.
Project discontinuation scenario D2	The householder does not use the clean cook stove, potentially re-selling the equipment, but uses a traditional cook stove instead.

Source: Authors' elaboration based on interviews and analysis of project design documents.

Figure 11 presents an initial overview of the technology, processes and financial implications typically involved in the continuation and discontinuation scenarios for household cook stove projects.

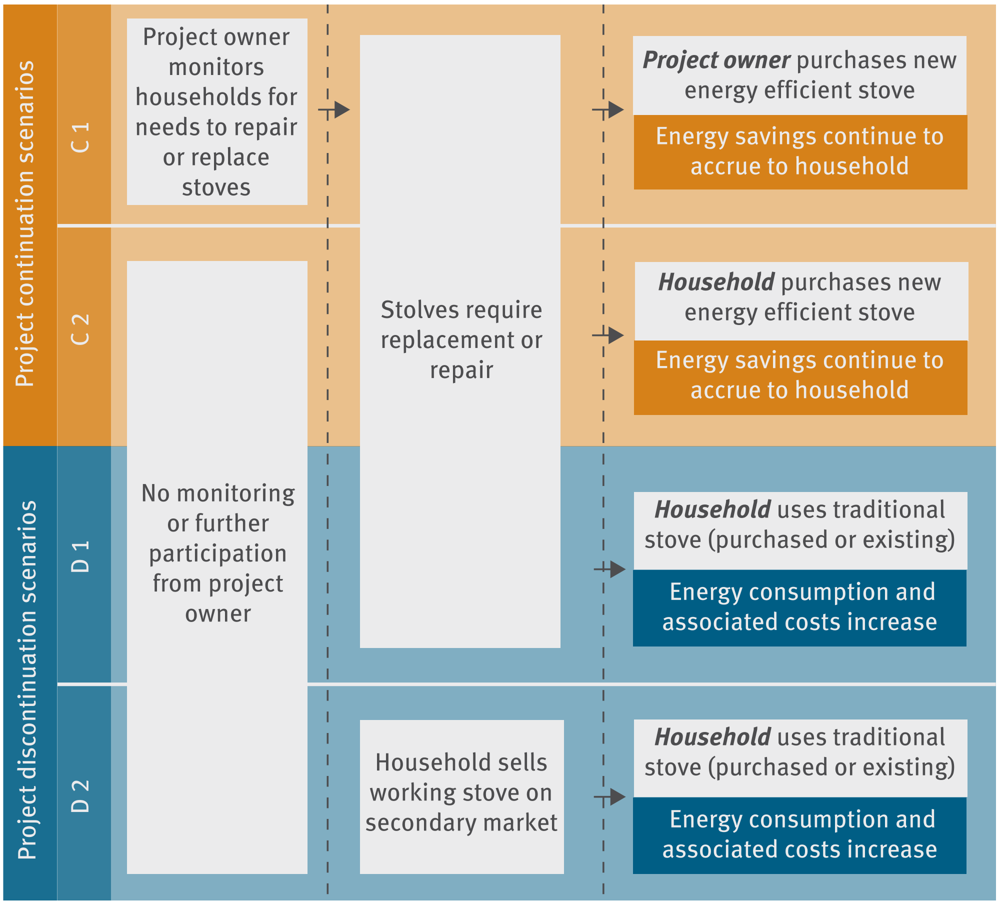


Figure 11: Overview of scenarios and processes for cook stove projects

7.3.2 Current status of projects

In research by Warnecke et al (2015), 26 projects for household cook stoves were randomly selected for evaluation, including 14 projects in India. Overall household cook stove projects in all countries analysed under the study demonstrate a project implementation rate of 71 %. A high proportion of household energy efficiency projects are projects with a registration date in 2012 and/or PoAs, and a number of projects are therefore still in the planning and implementation phases. However, there are also a number of projects being discontinued and dismantled, even amongst the 2012 registrations. In Kenya, only three of the seventeen registered CPAs under methodologies AMS-I.E and AMS-II.G have so far issued CERs since the start of their crediting period (UNEP DTU, 2016).

7.3.3 Overview of policy landscape

Conditions for the continuation of household cook stove projects in the absence of CER revenues may be heavily influenced by national policy. The most influential type of legislation, in this regard, would be legislation that explicitly requires the continuation of the activity:

- Such regulation might involve the phasing out of the use of traditional cook stoves by setting minimum efficiency standards for cook stoves. However, the difficulty of enforcing such legislation (i.e. high monitoring requirements) makes it necessary to provide complementary policies to support the adoption of newly installed clean cook stoves.
- The provision of subsidies, which could decline over time, would help encourage householders to purchase more energy efficient stoves or alternative renewable energy solutions. A declining value of any subsidy could be designed to not impact upon the commercialisation of stove technologies that will ultimately drive down prices increasing accessibility in the long term (Hude & Leader, 2014). Cook stoves could be further supported through the introduction of tax exemptions.
- Research and development in alternative technologies to traditional stoves could be pursued by governments to bring down technologies costs over time and enable households to switch to cleaner and more efficient alternatives.
- The training of local communities to use alternative technologies to traditional cook stoves and to improve land use practices (i.e. more sustainable production of wood fuels) could be provided by governments to encourage the uptake in use of newly installed clean cook stoves. In addition, policies that improve awareness of the social and environmental benefits of adopting newly installed clean cook stoves to the consumer (i.e. educational / promotional campaigns) would also be of benefit here.

An assessment of policies and measures in India and Kenya found that legislation does currently exist to support the uptake of newly installed clean cook stoves in households. Example of legislation in both countries include:

- Based upon information from the Global Alliance for Cookstoves, cook stove standards are currently in place in India (i.e. BIS 13152, Portable Solid Bio). In 2009, the Ministry of New and Renewable Energy in India launched the National Biomass Cookstove Initiative to enhance the use of efficient biomass cook stoves (Global Alliance for Clean Cookstoves, 2013b). The priorities of the initiative included 'state-of-the-art testing, certification and monitoring facilities and strengthening R&D programs in order to design and develop the most efficient, cost effective durable and easy to use devices' (Global Alliance for Clean Cookstoves, 2013b). In addition, a National Climate Energy Fund was set up in 2011 to finance research and innovative products in clean energy technology. Several project proposals under the scheme have also included subsidies for low carbon (Panda & Jena, 2012). However, there have been delays with the distribution of finance and questions raised regarding the efficient use of funds (Global Alliance for Clean Cookstoves, 2013b).

  The Indian government has long promoted the use of more efficient cook stoves over several decades – however the success of the schemes, such as the subsidies provided for biogas stoves under the National Biogas and Manure Management Programme, have been undermined by the lack of capacity building (i.e. to provide subsidies for the cost of maintaining cook stoves and policies to improve local skills). Although the government made money available for such improvements there was often a lack of awareness about the availability of such funds.

- Kenya has one standard on domestic biomass cook stoves (KS 1814-1:2005). The standard was established by the Technical Committee (TC) on Appropriate Technology (Global Alliance for Clean Cookstoves, 2013b). The country has also been involved in several projects to promote the use of more efficient cook stoves through capacity building using a countrywide network of Energy Centers, with the Ministry of Energy advocating two cook stove models/designs: the Kenyan Ceramic Jiko that uses charcoal, and the Maendeleo stove that utilises firewood (Global Alliance for Clean Cookstoves, 2013b).

  Following the 2016 annual budget in Kenya, the 16 % value added tax on liquefied petroleum gas (LPG) was removed only three years after its introduction.[33] In addition, import duties on cookstoves and fuels were reduced from 25 % to 10 %. Tax exemptions such as these are designed to support the cook stove value chain and ultimately reduce costs for the end user.

The Global Alliance for Clean Cook Stoves (2014) reported that 56 % of the cook stoves and fuels distributed by its partners between 2010 and 2014 were clean and/or efficient.[34] Given the high proportion of households that continue to use more traditional cook stoves, it is evident that further policy interventions are likely to be necessary in order to improve access to newly installed clean cook stoves. Table 44 summarises that no regulations currently prohibit or effectively phase out the use of traditional cook stoves in India and Kenya although both countries have implemented policies to encourage the uptake of the continuation scenarios.

Table 44: Regulations for cook stove projects in India and Kenya

Scenario	Compatibility of scenarios with regulations	
	India	Kenya
C1: Clean cook stove continues to be used and once broken replaced with a clean cook stove by the CDM project developer	✓	✓
C2: Clean cook stove continues to be used and once broken replaced with a clean cook stove by the householder.	✓	✓
D1: Clean cook stove continues to be used by the householder but once broken replaced with traditional cook stove.	✓	✓
D2: Clean cook stove not used but sold and replaced with a traditional stove.	✓	✓

7.3.4 Assessment of costs, financial benefits and barriers

Based upon the type of clean cook stove installed, a reduction in fuel wood consumption is expected to occur by either efficiency improvements in the combustion of fuel wood (i.e. improved cook stoves) or by the use of alternative technologies (i.e. solar cookers). Fuel cost savings depend upon how the fuel is acquired in the base case scenario (i.e. continued use of traditional cook stoves).

With few exceptions it is generally assumed within PDDs in Kenya that rural households using fuel wood gather it for free, while users of charcoal purchase their fuel (Lambe et al, 2015).[35] For many rural communities, the financial benefits accrue therefore more from realising the opportunity cost of reducing the time necessary for fuel wood collection and less respiratory problems for households increasing levels of productivity. Indeed, Lambe and Atteridge (2012) emphasise that gathering fuel wood is a task predominantly performed by women and children, which can take up to several hours to complete per day. This time could instead be more productively spent on income generating and educational activities.

33 http://cleancookstoves.org/about/news/06-22-2016-kenya-drops-trade-tax-barriers-to-aid-adoption-of-cleaner-cooking-technologies.html

34 India and Kenya are both considered as focus countries within the GACC initiative.

35 Data collection and analysis by Lambe et al (2015) involved a review of PDDs for all 31 of the carbon-financed cookstove projects in Kenya and 26 in-depth semi structured interviews with key actors.

The reported health benefits associated with clean cook stoves (i.e. reducing rates of indoor air pollution)[36] provide a further justification for households to purchase a newly installed clean cook stove.[37] However, Lambe et al (2015) suggest that project developers may nevertheless overestimate the incentive created by fuel savings from using improved cook stoves, especially when the fuel wood is collected free of charge.

Despite the financial and health benefits associated with newly installed clean cook stoves there are several barriers to their widespread adoption:

- The upfront cost of a newly installed clean cook stove is often the main barrier for the lowest income households – even if the design of the stove meets the needs and preferences of the end user (Lambe et al, 2015);
- Cultural preferences to use traditional stoves for the cooking of certain dishes (especially bread) – the quality of the food from traditional cook stoves is preferred by many communities. Many of the alternative cook stoves do not have a wider opening necessary for bread making. Some rural households have complained that it is not possible to cook for large families on clean cook stoves (Lambe and Atteridge, 2012).
- Lack of understanding of how to use clean cook stoves possibly due to households not attending training workshops organised by the project developer.
- The traditional cook stoves provide a greater level of space heating than more clean cook stoves and this was also cited as an issue preventing the use of alternative cook stoves.

In addition to information and insights from local experts, several projects from different countries were selected for analysis of financial conditions, according to the information included in, or attached to, their PDDs. The analysis shows the division of the costs and benefits of installing clean cook stoves between both the project developer and the householder. In this subsection, the costs and benefits of each of the scenarios are analysed. Costs are considered in terms of the subsidy provided by the project developer to the householder for newly installed clean cook stoves as well as ongoing operating expenditures and maintenance completed by the project developer. Householders primarily benefit from the installation of clean cook stoves via the reduction in fuel consumption and improved health benefits.

Table 45: Potential costs and financial benefits for clean cook stove project scenarios

Scenario	Operation and maintenance costs				Benefits	
	Monitoring households and conducting outreach (PD)	Replacement of EE cook stoves (PD)	Replacement of EE cook stoves (HH)	Purchase of traditional cook stove (HH)	Reduced wood fuel use (HH)	Sale of working EE cook stoves (HH)
C1: Clean cook stove continues to be used and once broken is replaced with a clean cook stove by the CDM project developer.	✓	✓			✓	
C2: Clean cook stove continues to be used and once broken is replaced with a clean cook stove by the householder.			✓		✓	
D1: Clean cook stove continues to be used by the householder but is eventually replaced with a traditional cook stove.				(✓)		
D2: Clean cook stove is not used but sold and replaced with a traditional cook stove.				(✓)		✓

Source: Authors' elaboration based on PDD analysis, interviews and literature. *PD* refers to project owners/administrators; *HH* refers to households. Brackets are used where the incurrence and accrual of costs and benefits is variable.

36 Studies show that replacing traditional cook stoves with newly installed clean cook stoves can reduce the number of deaths arising from indoor air pollution: a randomised control trial found that improved cookstoves reduced the incidence of severe forms of respiratory infection by around 30% (Smith et al. 2011).

37 However, research by Aung et al (2016) recently questioned the environmental impact of newly installed clean stoves. Improvements were less than anticipated following measurements of ambient and indoor household air pollution before and after a carbon financed approved cook stove intervention in rural India.

Project continuation scenario C1

Under scenario C1, project costs would be paid for by the project owner. The provision of a subsidy for the newly installed clean cook stove represents the main cost of the project developer. A common business carbon finance model for cook stove projects is using the carbon revenues to strongly or fully subsidise the costs of purchasing more expensive clean cook stoves (see Table 46). The uptake of newly installed clean cook stoves also relies upon outreach activities to educate householders on the benefits of the technology compared to traditional activities. Conducting outreach is an additional operational cost (along with ongoing maintenance requirements) for the project developer.

Cook stove projects are subject to the problem of divided (split) incentives. While the owner of the project pays for the installation of the clean cook stoves, it is the householder normally who accrues the direct benefits from any fuel savings. As a consequence, the owner of the project (i.e. the project developer) may only receive a financial benefit in the form of CER revenue. Without CER revenues, the financial incentive for continuing the operation of the project (i.e. maintaining/replacing clean cook stoves) becomes limited (in the absence of alternative revenue streams). In such circumstances, the continuation of the project beyond the lifetime of the distributed clean cook stoves could be called into question.

Based upon the responses from project developers involved in cook stove projects, it is very unlikely that broken cook stoves will be replaced by project developers in the absence of CER revenues. Given that the lifetime of the majority of cook stove models in Table 46 are under the 7 or 10 year CER crediting period applied to cook stove projects in both India[38] and Kenya[39] (refer to the UNEP DTU CDM/PoA Pipeline, January 2016), there is a considerable risk that cook stove projects could be discontinued without further support.

Table 46: Typical cook stove costs in developing countries in 2011

Stove type	Stove cost (US$)	Life of stove (years)
Traditional open fire	0	n/a
Traditional charcoal	3	2
Improved charcoal	6	3
Kerosene wick	6	3
Kerosene pressure	7	3
Artisan improved	5	1.5
New generation single-pot	25	5
LPG stove plus cylinder	100	10
New generation two-pot and chimney	50	5
Biogas system	300	10

Source: World Bank (2011)

Since the project developer would accrue costs with no financial benefits under scenario C1, the financial conditions for this scenario are very negative. Despite this general conclusion it should be noted that in some cases C1 might be viable if the project owner (i.e. an NGO) is motivated by non-financial incentives such as research or community development.

38 In India, all but one of the 29 CDM projects considered in this study started their crediting period after 2012 (UNEP DTU CDM/PoA Pipeline, January 2016).

39 In Kenya, the 17 CPAs considered in this study all started crediting after2012, with 4 of the CPAs only starting their crediting period in 2014 (UNEP DTU CDM/PoA Pipeline, January 2016).

Project continuation scenario C2

According to several project developers, the success of clean cook stove projects depends upon the continued presence of project owners to support the building of local capacity to educate on how to use, maintain and repair the clean cook stoves that have been subsidized through carbon finance. In the absence of project owners, there is certainly a risk that householders will revert to traditional cook stoves once the newly installed clean cook stoves fail. Despite the benefits associated with using a newly installed clean cook stove, such as potential fuel cost savings and improved health from air quality, the upfront costs often prevent households from being able to afford to move away from traditional cook stoves (refer to previous discussion on the incentives and barriers associated with cook stoves).

In summary, the financial conditions for households under scenario C2 are variable per case and non-conclusive, but the barriers related to upfront costs for replacement and cultural preferences are considered insurmountable in most cases.

Project discontinuation scenarios

As discussed in the previous section (refer to project continuation scenario C2) it is likely that the householder will not be able to afford to purchase a replacement clean cook stove and will therefore revert to the use of a traditional cook stove, including either a three-stone stove setup, an existing traditional cook stove, or a new traditional cook stove (purchased for a far lower cost than a new clean cook stove). This of course primarily depends on the financial position of the household but other barriers may also influence decision making.

The householder owns the clean cook stove with the project developer simply providing a subsidy to enable the barrier of capital costs to be overcome. Financial benefits may theoretically be accrued by the householder through the sale of the clean cook stove, but this potential is rather limited. The potential resale value of cook stoves is low with any attempt to recover the original capital expenditure undermined by the high transaction associated with any sale (i.e. identification of a buyer in a limited market for used equipment). It is more likely that the clean cook stove will simply remain with the household as long as the technology benefits the end user. No non-financial barriers necessarily exist to prevent the project discontinuation scenarios. However, if alternative cook stoves (e.g. LPG stoves) were also considered in these discontinuation scenarios, it is likely that the operational cost of the fuel would be deemed too expensive to use for all cooking tasks (Lambe and Senyagawa, 2015).

7.3.5 Summary of vulnerability and scenarios for energy efficient cook stove projects

Table 47 shows the potential scenarios for cook stove projects in order of their financial attractiveness regarding the ongoing costs and benefits. The information relates only to ongoing financial flows and does not include upfront capital expenditures. Table 47 shows that project continuation scenario C2 could potentially be economically more attractive than the discontinuation scenarios, assuming no major barriers. However, the major barriers identified for scenario C2 are understood to be too great for the scenario to be feasible. As such, discontinuation scenario D1 (newly installed clean cook stove continues to be used by the householder but once broken replaced with a traditional cook stove), is the most likely scenario in both countries analysed.

Table 47: Summary of the assessment of cook stove project scenarios

Scenario	Compliance with regulations	Financial conditions	Barriers and mitigation factors in analysed countries
C2: Clean cook stove continues to be used and once broken is replaced with a clean cook stove by the householder.	✓	Positive to neutral	Barrier: High (upfront costs, lack of awareness, cultural preferences)
D1: Clean cook stove continues to be used by the householder but once broken is replaced with a traditional cook stove.	✓	Neutral (case specific)	-

D2: Clean cook stove is not used but sold and replaced with a traditional cook stove.	✓	Negative	Mitigating factor: Potentially still possible in the case that knowledge on benefits is lacking, or money is needed in the short term.
C1: Clean cook stove continues to be used and once broken is replaced with a clean cook stove by the CDM project developer	✓	Very negative	-

To summarise, the use of newly installed clean cook stoves is likely to continue as long as benefits occur for the householder. However, when clean cook stoves fail, more inefficient traditional cook stoves will most likely be bought by households instead due to the lower capital costs. Given the need to replace cook stoves within the CER crediting period, cook stoves projects in India and Kenya are considered a high risk of discontinuation, and support may be required to ensure the mitigation potential is realised.

7.4 Summary of Vulnerability for Household Energy Efficiency Projects

The analysis of household efficiency projects has demonstrated major differences in the conditions and prospects of different project subtypes.

Table 48 summarises the conditions for household energy efficiency projects, according to the analysis performed in the previous sections.

- Lighting projects are considered to be at low risk of discontinuation in Mexico, India and Pakistan. In Mexico, regulations require the continuation of the project. In India and Pakistan, it is determined that households are likely to finance replacement of bulbs due to their increasing market presence, the decreasing costs and improving knowledge on their benefits.
- Cook stove projects are considered to have a high risk of discontinuation in India and Kenya. Regulations do not require the continuation of the use of efficient stoves in both countries. Project owners have no incentive to continue financing replacement stoves and households are highly unlikely to finance this due to the considerable costs and other barriers including knowledge of benefits and cultural preferences.

Table 48: Summary of vulnerability of household energy efficiency projects

	India	Pakistan	Mexico	Kenya
Energy efficient lighting	Low risk	Low risk	Low risk	Not evaluated
Energy efficient cook stoves	High risk	Not evaluated	Not evaluated	High risk

8 Mitigation Impact of Continuing GHG Abatement in Vulnerable Projects

In the previous chapters we have assessed selected project types with regard to their vulnerability of stopping GHG abatement, taking into account incentives and barriers for project owners as well as the policy context of the host country. In this chapter we assess the mitigation impact of ensuring continued GHG abatement in projects that were identified as vulnerable of stopping GHG abatement, before we explore in the next chapter policy options to ensure continued GHG abatement.

The analysis includes the following project types, which were assessed to have a high or medium risk of project discontinuation in the previous sections:

- Commercial livestock manure management projects in Mexico and Brazil *(High risk)*
- Palm oil solid waste composting in Malaysia *(Medium risk)*
- Independent biomass power producer projects in India *(High risk)*
- Captive biomass energy projects in India *(High risk)*
- Energy efficient cooking stove projects in India and Kenya *(High risk)*

8.1 Approach for Assessing the Mitigation Impact of Continuing Vulnerable Projects

Overview of methodology

The mitigation impact of ensuring continued GHG abatement of projects depends on various direct and indirect aspects. We assess the impact on emissions, by comparing the continued project operation with the most likely discontinuation scenario, focusing on the following aspects:

1. Direct emission reduction potential
2. Relationship between the activity and international climate pledges
3. Potential for perverse incentives in policy making
4. Transformational change potential of the activity

Aspect 1: Direct emission reduction potential

As a starting point, additionality – i.e. whether a mitigation action is pursued due to the incentives of the policy intervention – is a key pre-requisite for achieving emission reductions. The assessment of the additionality of mitigation actions depends on the intervention and point in time when the intervention occurs:

Additionality at the start of a mitigation activity: All CDM projects have to demonstrate additionality at the time of the initial decision to proceed with the implementation of the project (under the CDM referred to as the „start date“ of the projects). Additionality of the project at its start date was demonstrated in the PDDs, validated by Designated Operational Entities and accepted by the CDM Executive Board for registered projects. Moreover, for projects that are vulnerable of stopping GHG abatement, it is highly likely that they were additional at the start of the mitigation activity, since even based on their ongoing costs and benefits - without considering the initial capital investment - they are assessed to be unattractive to pursue. Carbon revenues (or other support) are essential to continue GHG abatement. We therefore assume that additionality at the project start is a given for project types identified as vulnerable of stopping GHG abatement. It is important to note that if projects are not vulnerable of stopping GHG abatement, it does not imply that they are not additional. Their additionality also depends on investment costs and barriers to investment which are not assessed as part of this report.

Additionality of providing support after project implementation: After project implementation, support may be provided to projects to ensure their continued operation. The additionality of such support has to be assessed from a different angle: i.e. whether or not project continuation would be warranted without such support under the current conditions. We assess the additionality of providing such support through the methodology in section 2.1 where we assess whether continued project operation is likely under current conditions, taking into account applicable laws and regulations, costs and benefits, as well as relevant barriers. Hence, providing additional support is likely to be additional for those projects that are assessed to be likely vulnerable of stopping GHG abatement.

In summary, for projects that are assessed to be vulnerable of stopping GHG abatement both additionality at the project start and additionality of providing support in the current situation is likely. We therefore do not separately assess additionality for the identified project types.

To quantify the direct emission reductions from ensuring continued GHG abatement, we compare the project continuation scenario with the most likely project discontinuation scenario. It is important to note that the mitigation impact of ensuring continued abatement of existing projects might be different than from starting new projects. Other than for new projects, the mitigation impact of ensuring continued abatement of existing projects has to be assessed by comparing the scenario of continued project implementation with the most plausible scenario for project discontinuation. The most plausible scenario for project discontinuation might in some situations, however, differ from the most plausible baseline scenario at the project start, since other scenarios are available to the project owner before and after project implementation. For example, when replacing an existing, in-efficient coal power plant by a new, more efficient biomass plant, a plausible baseline scenario is the continued operation of the existing coal power plant. However, once the new biomass power plant is installed, reinstalling the old power plant is not any longer a plausible scenario. A more plausible project discontinuation scenario could be using fossil fuels in the new biomass power plant.

As a first step, we therefore identify the most plausible project discontinuation scenario. This is determined in the process of the assessment of project type vulnerability. The methodology is described in section 2 and executed for eight project subtypes in sections 5, 6 and 7.

It is then assessed whether the most likely discontinuation scenario is similar to the baseline scenario identified at the project start:

- In some cases, the ***project discontinuation scenario would be exactly the same as the baseline scenario*** identified at the project start, in which case the emission reductions reported by the project can be taken as a good estimate for the scale of emission reductions that would not occur in the case that the project discontinues its mitigation activity. To quantify emission reductions, ex-ante emission reduction estimates from PDDs are used; data from monitoring reports would be more accurate but are difficult to compile, as monitoring reports have flexible start and end dates. It is also considered to what extent the emission reduction estimates in project design documents are known to have been over- or under-estimated.
- For projects where the ***discontinuation scenario differs from the PDD baseline scenario***, alternative means were taken to estimate the emission reduction impact. For example, in this study, the discontinuation scenario for palm oil solid waste composting projects differed from the baseline scenario, due to local changes in the market demand for palm oil solid wastes. In this case, local expert insights were used to qualitatively assess the difference between the mitigation impact of the project activity continuation with the alternative uses of the solid wastes given the new markets, resulting in the assumption that there was likely to be no significant difference in the mitigation outcomes between the project continuation and discontinuation scenarios as the alternative uses of the solid wastes would also prevent their decay and the associated emissions (see section 8.3).

Should the information available allow for such an analysis to be completed, the result of this process will be an indicative quantification on the aggregated emission reduction impact for each vulnerable project type in each of the countries.

Figure 12 presents an overview of the steps taken in the determination of the emissions impact from the project discontinuation scenario, compared to that of the project continuation scenario.

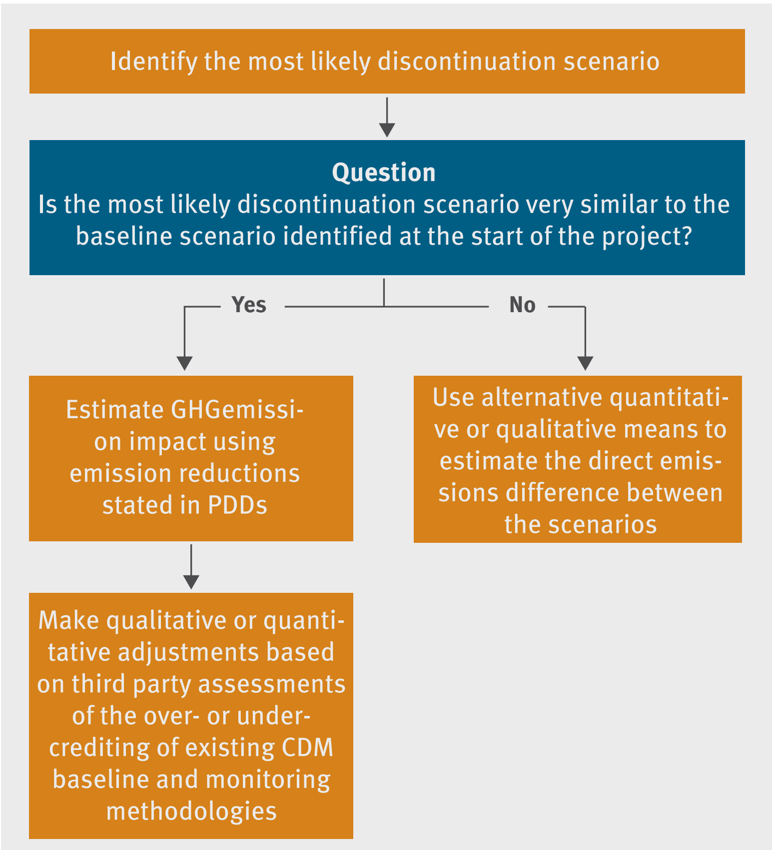


Figure 12: Steps taken to determine the direct emissions reduction potential

Aspect 2: Relationship between the activity and international climate pledges

We assess for each vulnerable project type whether the mitigation activity falls within the scope of mitigation pledges under the Cancun Agreements and NDCs. This information is helpful to understand whether support for projects helps host countries achieving their international mitigation pledges or whether it leads to reductions beyond international mitigation pledges. It is also important to recognise that inclusion in the NDCs does not necessarily mean that countries have suitable policies in place to address the emissions.

Aspect 3: Potential for perverse incentives in policy making

In some cases, continued crediting or other forms of direct financial support of projects might provide disincentives for policy makers to introduce policies to abate the emissions, because the introduction of such policies may reduce the crediting potential and associated financial flows. The risk for such disincentives may depend on the project type (Schneider et al. 2014). We briefly assess the risk for each project type, considering whether policies for that project type are common in more developed countries and the potential co-benefits of introducing policies for the host country.

Aspect 4: Transformational change potential of the activity

Many international finance institutions intend to support activities that contribute to long-term transformational change towards a low carbon economy (Schneider et al. 2015). For example, the GCF seeks to "promote a paradigm shift towards low-emission and climate-resilient development pathways", the United Kingdom's International Climate Fund (ICF) expects that supported actions should achieve "change which catalyses further changes, enabling either a shift from one state to another [...] or faster change" (ICAI 2014), the NAMA facility's overall objective is to achieve "transformation towards a low carbon society in line with the 2°C limit" (NAMA Facility 2015). The Climate Investment Fund (CIF) aims at „delivering investment to stimulate transformation" (CIF 2015a), and the Clean Technology Fund (CTF), which is one funding window of the CIF, aims at catalysing „transformative change that can be replicated elsewhere" (CIF 2015b). Drawing upon earlier work (Schneider et al. 2015), we briefly assess for each project type whether continued abatement is likely to foster, or rather impede transformational change towards a low-carbon economy. Towards this end, we use three simplified criteria to assess the potential to foster, and not impede, transformational change:

- Risk for carbon „lock-in": this refers to "the dynamic whereby prior decisions relating to GHG-emitting technologies, infrastructure, practices, and their supporting networks constrain future paths, making it more challenging, even impossible, to subsequently pursue more optimal paths toward low-carbon objectives through these investments" (Erickson et al. 2015a). These could include technologies that are less carbon-intensive than currently available technologies but that are not compatible with the low carbon development in a longer-term perspective.
- Potential for replication: this refers to measures that others can copy, leading to larger scale or faster roll-out (ICAI 2014).
- Potential for innovation: this refers to the potential for technological improvements or more radical change in technologies or practices applied.

The approach presented here for the assessment of the mitigation impact for providing support for project continuation is applied for vulnerable project types in the following sections.

8.2 Commercial Livestock Manure Management Projects in Mexico and Brazil

Project discontinuation scenario

In section 5.2, the following discontinuation scenario was identified as the most likely scenario:

> *Manure is collected from livestock confinement facility and continues to be disposed in the existing lagoons, but the covering membranes are removed or trapped gas is released. The manure decays, causing emission of methane, while the remaining sludge is applied to the land.*

This scenario is understood to fit the very large majority of commercial livestock manure management projects in Mexico and Brazil. Only 2 projects in Mexico and between 2 and 5 projects in Brazil could be identified that may deviate from the conditions underlying the conclusion. It was also highlighted that while the conclusion applied to the majority of projects generally, some of the larger individual farms might continue to mitigate; most projects controlled emissions on multiple farms, and there are indications that barriers for the financially attractive continuation scenarios may have been overcome on a small number of individual farms.

Direct emission reduction potential

The projects analysed for this study included those with methodologies AMS-III.D. – Methane recovery and flaring or utilisation in animal manure management (small scale) – and ACM10/AM16/AM6 – Destruction of methane emissions and displacement of a more-GHG-intensive service (large scale, AM6 and AM16 were superseded by ACM10).

For AMS-III.D projects, the baseline of the CDM project methodology is defined as follows (UNFCCC, 2015):

> *The baseline scenario is the situation where, in the absence of the project activity, animal manure is left to decay anaerobically within the project boundary and methane is emitted to the atmosphere.*

The ACM10 methodology document for large scale projects offers more flexibility on the construction of the baseline scenario, but the projects using this methodology in Mexico and Brazil use the same baseline as that identified above.

The baseline scenarios for these methodologies are considered to be the same as the identified likely project discontinuation scenario. Therefore, the emission reductions of project design documents are taken as a basis for the determination of the direct emission reduction potential.

According the pre-implementation emission reduction calculations in PDDs, the total annual emission reduction potential for these projects in Mexico and Brazil is 2.83 M t CO_2e and 2.63 M t CO_2e, respectively. However, manure management projects issued on average less CERs than expected in PDDs. The average level of actual CER issuance up to January 2016 has been 61 % lower for Mexico and 47 % lower in Brazil than the projects' ex-ante issuance estimates (UNEP DTU, 2016), including only those projects where credit issuance actually occurred. This could be due to lower volumes of manure than predicted, lower methane generation rates or a delayed implementation of the projects. The two early methodologies AM0006 and AM0016 were withdrawn in 2006, when the consolidated methodology ACM0010 was approved to replace them. ACM0010 determine emission reductions in a more conservative manner. At the renewal of their crediting period, projects that initially applied AM0006 or AM0016 have to apply the currently valid methodology ACM010. This may lower the emission reduction potential of projects that used AM0006 and AM0016 in their first crediting period and would apply ACM0010 in their second and third crediting periods. Estimating the effect is, however, difficult without evaluating the specific circumstances of individual projects. Therefore, this effect is not estimated in further detail; rather, it is broadly assumed that approximately half of the discrepancy between anticipated emission reductions and issuance rate is due to ex-ante over estimations of the emission reduction potential. The ex-ante volume in PDDs is therefore reduced by 30 % in Mexico and 23 % in Brazil to derive the emission reduction potential.

Table 49 shows that the total annual emission reduction potential for these projects, according to the pre-implementation emission reduction calculations in PDDs and adjustments based on the actual issuance success, is approximately 2 M t CO_2e in Mexico and also approximately 2 M t CO_2e in Brazil. Of this combined 4 M t CO_2e, just 0.1 M t CO_2e accrues to projects that are considered less likely to follow the identified discontinuation scenario. As such, the maximum annual mitigation impact of support for these projects could be considered to be approximately 3.9 M t CO_2e.

This estimate may be considered an upper range of the potential mitigation impact; as highlighted, it is a possibility that some of the individual farms contained within projects prone to the discontinuation scenario might still continue, despite the majority of farms being known to have already discontinued.

Such situations are estimated by local stakeholders to be the exception, rather than the norm, and to apply to only a small proportion of farms. Nevertheless, this must be considered when discussing the potential mitigation impact.

Table 49: Summary of emission reduction potential for manure management projects in Mexico and Brazil

	Mexico	Brazil
Total number of projects	99	59
Total annual emission reduction potential in first crediting period	2 M t CO_2e/year	2 M t CO_2e/year
…of which considered less likely to follow the identified discontinuation scenario	*0.02 M t CO_2e/year*	*0.10 M t CO_2e/year*

Source: Calculated with data from the UNEP DTU CDM Pipeline (UNEP DTU, 2016)

Relationship between the activity and international climate pledges

Mexico

Mexico's NDC features an economy wide target for the basket of all Kyoto GHGs in its first commitment period as well as black carbon. Mexico also included an economy wide GHG target for the period up to 2020 in its Cancun pledge, based on the 2009 Special Programme on Climate Change. The NDC explicitly states that it includes manure management in the agriculture sector within its sectoral scope (Government of Mexico, 2015).

It is stated that the NDC is consistent with Mexico's 2012 General Law on Climate Change (LGCC), which in turn is operationalised by the 2014-2018 Special Program on Climate Change (PECC). Neither the LGCC nor the PECC make specific reference to activities for methane emissions from livestock manure management. As such, although it is specified that livestock falls within Mexico's overall economy wide emissions target, the subsector does not appear to be a priority for the strategies intended to implement this target, according to the more detailed policy documents and strategies. Increased efforts in livestock manure management could empower Mexico to implement more action in this sector and subsequently to increase or overachieve their overall emissions target. It could also cause the country to reduce efforts in other areas if overachievement is forecast. It is unclear whether such a link will be made.

Brazil

Brazil's NDC, as well as their pledge under the Cancun Agreement, also features an economy wide target; the NDC states that it covers all GHGs from 100 % of the territory (Federative Republic of Brazil, 2015). Livestock manure management is not named specifically but is understood to be included within this scope.

The NDC includes the statement that Brazil intends to strengthen the Low Carbon Emissions Agricultural Programme (ABC). The ABC Programme includes the aim to improve technologies to manage livestock waste, although it does not anticipate any direct tangible emission reductions in the scope of the ABC Programme from manure management, unlike it does for other emission sources (WRI, 2013).

Like for Mexico, although the manure management project activities fall within Brazil's overall economy wide emissions target, the subsector does not appear to be a priority for the strategies currently envisaged to implement this target. Increased efforts in livestock manure management could empower Brazil to increase or overachieve their overall emissions target. It could also cause the country to reduce efforts in other areas.

Potential for perverse incentives in policy making

The available information on national policies in Mexico and Brazil suggests that addressing methane emissions from commercial manure management is not a policy priority. The projects generate sustainable development co-benefits, such as income generation or reduction of odour, but these benefits do not appear to be high on the political agenda. It therefore seems unlikely that continued international support based on credit purchase programmes would have a strong impact on policy making in the sector.

Transformational change potential of the activity

Livestock production is likely to continue to play a major role in many countries, including livestock kept in enclosure. As such, effective manure management will need to form part of long-term low carbon development strategies. Projects collecting methane from manure management and utilizing the methane for energy generation while generating compost is highly likely to be part of such long-term strategies as other mitigation options in this area are rare. However, these do not pose significant risks for carbon lock-in, as they can easily be adapted by upgrading capture technology, co-digesting other forms of waste, or deploying more efficient technologies for biogas use. The technologies are well developed, no major break-through or strong cost reductions can be expected from larger scale role out and deployment. However, there is significant potential for replication, as livestock operations exist in many countries.

Summary of mitigation impact

Overall, we estimate that registered CDM projects in Brazil and Mexico could provide emission reductions of about 4 M t CO_2e per year if continued or renewed abatement is supported. Replicating these projects in other countries could potentially increase the volume.

8.3 Palm Oil Solid Waste Composting in Malaysia

Section 5.4 found that the risk of discontinuation for palm oil solid waste compositing projects was *uncertain*, since variable local conditions may favour continuation of the activity in some cases or local factors may provide barriers, which result in discontinuation.

Research by Warnecke et al (2015), found that at least one third of the 33 composting projects in Malaysia were abandoned shortly after project registration and did not proceed to implementation. The technical implementation of these projects never took place, so the mitigation potential is not "retrievable" through support schemes.

Project discontinuation scenario

For projects where the barriers identified for the continuation scenario are too great, the following discontinuation scenario was identified as the most likely scenario:

> *The composting operation stops. Palm oil processing residues are sold for alternative uses.*

Various alternative uses were identified for palm oil solid wastes in section 5.4.4, including paper production, basic road surfacing material, production of medium-density fibreboard (MDF) and blackboards, briquettes, hydrogen fuels and biomass energy. The specific alternative use is highly variable according to the present market conditions in each local area.

Direct emission reduction potential

The projects analysed for this study included those with the methodology AMS-III.F.: Avoidance of methane emissions through composting.

For AMS-III.F. projects, the baseline of the CDM project methodology is defined as follows (UNFCCC, 2011):

> *The baseline scenario is the situation where, in the absence of the project activity, biomass and other organic matter (including manure where applicable) are left to decay within the project boundary and methane is emitted to the atmosphere.*

Emissions reductions under the project are achieved through the prevention of methane emissions from the uncontrolled decay of the organic matter.

It was found that the risk of discontinuation is uncertain since the conditions for some projects are likely to be conducive to continuation. Analysis from Warnecke et al. (2015) and expert insights lead to the broad assumption that conditions may be conducive for continuation for roughly half of the projects in Malaysia that had reached technical implementation. For these projects, the provision of support would clearly entail no mitigation impact, since the continuation of the activity would happen with or without the support.

For all of the various alternative uses of the solid wastes, it is understood that there is no significant difference in the mitigation outcome between the continuation and the discontinuation scenario, since all of the various uses of solid wastes should avoid the situation that methane is emitted due to decay. Some of the processes that take place under the alternative uses may entail energy related emissions, but it is assumed that such energy consumption would be required for these processes whatever material would be used for the purpose, and a more detailed analysis of the processes for each potential use is beyond the scope of this study. As such, it is generally assumed that there would also be no direct mitigation impact for the provision of support to projects at risk of discontinuation.

Relationship between the activity and international climate pledges

Malaysia's INDC includes an economy wide emissions reduction target, which explicitly includes methane emissions from the agriculture sector. Malaysia did not make a formal pledge under the Cancun Agreement.

While methane from the agriculture sector is included in Malaysia's economy-wide target, it is unclear whether or not specific measures are intended for methane in the agriculture sector, in order to meet this target.

Potential for perverse incentives in policy making

The available information suggests that it is unlikely that the possibility for continued international support through crediting would create perverse incentives in policy making. This disposal or other use of empty fruit bunches – other than open field burning which is prohibited in Malaysia – is not regulated by policies and it is unlikely that policies will be introduced in the near future which require project developers to compost empty fruit bunches. As such, it is unlikely that continued crediting would impact the policy making in Malaysia.

Transformational change potential of the activity

Palm oil is mainly used in the food and biofuel industry. The production of palm oil in Malaysia is subject to considerable controversy. Palm oil production is considered as one of the main drivers for deforestation in Malaysia (Carlson et al., 2012; Koh & Wilcove, 2008), leading to the conversion of peat land with considerable impact on GHG emissions as well as loss of biodiversity. This is driven by growing demand for palm oil, including for the production of biodiesel.

Supporting the composting of solid palm oil waste is unlikely to affect this development. Crediting generates an additional cash flow for the operators of palm oil plantations. Depending on the market price of credits, crediting could make palm oil production economically more attractive, which could theoretically lead to a further expansion of the use of palm oil, compared to alternative – and possibly more sustainable – raw materials. In practice, this effect is likely to be small, as the revenues from compositing of palm oil solid waste are not large in relation to the value of the palm oil. Nevertheless, whether or not further revenues the palm oil industry are appropriate may be a politically sensitive issue, due to the broader potential environmental impacts of palm oil production.

In this regard, programs supporting composting of palm oil solid waste could consider ways to provide incentives for sustainable palm oil production. They could, for example, limit the program to companies or plantations that have been certified for sustainable palm oil production, not involving deforestation. Though this may not have an immediate effect, it may provide additional incentives for operations that are operating in more a sustainable way, which could have an impact in a more long-term perspective.

Composting is a technology that can be considered as a technology compatible with long-term transformational change. It does not lead to any lock-in. The technology is well developed and could be further replicated in developing countries.

Summary of mitigation impact

Based on the available information it is questionable whether continued support to projects compositing palm oil solid waste in Malaysia would have a mitigation impact.

8.4 Captive Biomass Energy and Biomass IPPs in India

Due to the overlaps in the conditions discussed for this section, both vulnerable biomass energy project types in India – independent power producers and biomass captive energy – are discussed in this chapter together.

Project discontinuation scenario

Independent power producers

In section 6.4.5, the following discontinuation scenario was identified as the most likely scenario:

Power plant is closed down.

The closure of the power plant is considered the most likely scenario for most projects, although the variability of conditions related to the local biomass market means that there may be some projects for which the conditions are conducive to continuation.

Biomass captive energy

In section 6.4, the following discontinuation scenario was identified as the most likely scenario:

The facility reverts to the use of existing standby technologies that use coal and/or to electricity sourced from the national grid, for their energy needs.

In the case that existing standby technologies do not exist, the following discontinuation scenario was identified as the most likely course:

The facility feeds coal into the boilers installed under the project activity, for their energy needs.

It is not certain which proportion of projects would be more prone to the first discontinuation scenario, and which proportion would be prone to the latter. From a selection of 20 projects, approximately half of those projects stated the availability of existing standby technologies, whilst the remaining half did not. It is therefore assumed that approximately half of the projects proceed along the course of the first discontinuation scenario, and half along the other.

Direct emission reduction potential

Independent power producers

It has been identified that there might be a small number of IPP projects for whom conditions are conducive for continuation; due to the highly local nature of these conditions, it is not possible to estimate more precisely what proportion of projects may be in a position to continue. For the sake of the estimate of the direct emissions reduction potential, it is assumed in this case that all projects are at risk of discontinuation.

The IPP projects analysed for this study included mostly those with the methodology AMS-I.D. – Grid connected renewable energy generation (small scale).

For AMS-I.D projects, the baseline of the CDM project methodology for the electricity generation is defined as follows (UNFCCC, 2013):

The baseline scenario is that the electricity delivered to the grid by the project activity would have otherwise been generated by the operation of grid-connected power plants and by the addition of new generation sources into the grid.

This baseline scenario appears also a reasonable representation of the project discontinuation scenario. The electricity of the project plant would need to be provided by other plants in the grid, which could include both existing and newly installed plants.

However, the emissions impact from discontinuation of biomass power plants also depends on the fate of the biomass residues if the project is closed down. Two potential discontinuation scenarios can be distinguished for the fate of the biomass residues:

a) the biomass residues would be used by other users in the market;
b) the biomass residues would not be any longer collected and left to decay.

These two discontinuation scenarios for the biomass residues have different impacts on GHG emissions. Under scenario (a), the emissions impact is likely to be similar to that of continuing the CDM project activity. Some, probably most, of the competing potential biomass users also seek to procure the biomass for energy, likely resulting in similar emission reduction outcomes. Under such simplified assumptions, the mitigation impact of supporting the continuation of the CDM projects could be considered to be approximately zero, since their continuation would be at the expense of other emission reducing users elsewhere. Under scenario (b), emissions would increase, due to electricity generation in other plants in the grid, and possibly due to the generation of methane from the decay of biomass. The increase in emissions can be deemed similar to the emission reductions of the project activity in PDDs.

To assess the project discontinuation scenario for biomass, several factors should be considered. A major factor supporting the scenario that the biomass may be used elsewhere, is that the price of supplied biomass is understood to be greater than the price of supplied coal in the majority of cases. It must be assumed that at least part of the reason why the price of biomass is greater than the price of coal is the scarcity of the commodity, and competition amongst potential biomass users; as such, it can also be assumed that any biomass not used by discontinued CDM projects would instead be used elsewhere. However, there are also reasons to question these assumptions. It is understood that the scarcity of biomass, at least in some local areas, is an artificial scarcity. The supply of biomass to the market is considered far short of its potential, due partly to imperfect knowledge and access to information on opportunities to sell biomass, as well as current sale prices that can be obtained, on the part of potential suppliers. Interventions which improved information flows to potential suppliers, such as capacity building or a more formalized biomass market through standardization and trade platforms, would, in turn, result in an increased supply of biomass to the market. This increased supply could accommodate the demand of the CDM projects alongside the other users with which these projects currently compete. Moreover, an increased volume of demand-side market participants – achieved, for example, through supporting the continued presence of the CDM project activities in the biomass market – might provide a natural driver for overcoming barriers for potential suppliers, such as lack of knowledge about opportunities to sell biomass.

As such, the direct emission reduction potential for the provision of support is unclear, depending on local conditions and the development of the biomass market in the coming years.

According to information from PDDs, the total annual emission reductions expected from biomass IPP projects in India in their first crediting period was 4.6 M t CO_2e (UNEP DTU, 2016). For projects with successful credit issuance, projects issued on average 9 % fewer credits than their ex-ante estimations (UNEP DTU, 2016); in line with the methodology outlined in section 8.1, it is generally assumed that approximately half of the underperformance in credit issuance is due to ex-ante over estimations of the emission reduction potential. As such, it could be deduced that the maximum direct annual mitigation potential of the biomass IPP projects in India could be approximately 4.4 M t CO_2e, if the discontinuation scenario were assumed to be in line with the project methodologies' baseline scenario, and assuming that projects would use excess biomass supply that would otherwise not be supplied to the market but rather left to decay or landfilled. This is an indicative estimate, since the average annual emission reductions in the first crediting period may not be an accurate indication of the present potential for all projects. On the other hand, if one assumes that the supply of biomass to the market remains limited as it presently is, and that the biomass would continue to be used by other competing entities, the emission reduction is close to nil.

Biomass captive energy

The captive energy projects analysed for this study included mostly those with the methodologies AMSI-I.C. – Thermal energy production with or without electricity (small scale), and AMS-I.D. – Grid connected renewable energy generation (small scale).

For AMS-I.C projects, the baseline of the CDM project methodology is defined as follows (UNFCCC, 2012):

> *Energy generation (thermal heat and / or electricity) is supplied by more carbon-intensive technologies based on fossil fuel.*

For AMS-I.D projects, the baseline of the CDM project methodology is defined as follows (UNFCCC, 2013):

> *The baseline scenario is that the electricity delivered to the grid by the project activity would have otherwise been generated by the operation of grid-connected power plants and by the addition of new generation sources into the grid.*

For projects with methodology AMS-I.C., the methodology baseline is a similar scenario as the discontinuation scenarios. It is generally assumed that for projects with electricity exports to the grid (AMS-I.D.), the generation of excess electricity for export will cease to continue in the project activity. Under such an assumption, the discontinuation scenario can be considered to be equal to the methodology baseline. The potential error margin from the mitigation potential associated with this assumption are considered to be minimal, since even in the cases that the assumption does not carry, the emissions intensity from the production of electricity on the project site using fossil fuels will likely be comparable to the emissions intensity of grid-connected power plants.

As such, the emission reduction potential from PDDs is taken as a basis for an estimation of the potential mitigation impact of the provision of support for continuation. The total of the average annual emission reductions predicted by PDDs for biomass captive energy projects in India is 3.01 M t CO_2e. For projects with credit issuance, the average issuance success rate was 78 %. Assuming broadly that approximately half of the under-performance of crediting was related to an overestimation of the mitigation potential in the ex-ante methodologies, it is considered that the potential mitigation impact, adjusted for PDD overestimations, may be approximately 2.7 M t CO_2e per year.

However, as for IPP projects, it is not certain that supporting the continuation of these projects would actually entail any significant mitigation impact, in the short term at least, due to the competition for biomass resources. Unless the conditions for biomass supply are enhanced, biomass utilised for captive energy projects would be diverted away from other uses, most of which would also be utilising biomass for energy. This issue is discussed in greater detail for IPPs in the previous section.

Relationship between the activity and international climate pledges

India's NDC includes two specific contribution targets that are related to the use of biomass for electricity generation (Government of India, 2015):

- To reduce the emissions intensity of its GDP by 33 to 35 percent by 2030 from 2005 level.
- To achieve about 40 percent cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030 with the help of transfer of technology and low cost international finance including from Green Climate Fund (GCF).

India's pledge under the Cancun Agreement also includes an emissions intensity target for the period up to 2020 (reduction of 20 to 25 per cent by 2020 from 2005 level), although this target explicitly excludes emissions from the agriculture sector.

The NDC submission document also contains background information on policies, actions and further targets, which we interpret to be the measures planned to achieve its NDC. Analysis from the Climate Action Tracker indicates that these current policies would lead India along a trajectory whereby it would meet the NDC emissions intensity target, while the 40 % non-fossil fuel power target is only very slightly more ambitious than the polices and measures already in place. Among these existing policies and measures are plans to increase the installed capacity of biomass power generation from 4.4 GW in 2015 to 10 GW in 2022 (Government of India, 2015).

As such, one might conclude that the continuation of biomass IPP projects may be a key area for the achievement of renewable energy target in the countries' NDC. In this regard, international support could be a viable option since the NDC target clearly states that it is subject to access to international finance sources.

Since India's NDC emissions intensity target is economy-wide, this also includes activities in industry including captive biomass energy projects. However, there are no specific targets or measures reported in the NDC that are specific to the generation of captive energy from biomass.

The Climate Action Tracker (2015) finds that the implementation of India's electricity sector targets alongside other associated planned policies will result in the economy-wide emissions intensity target (which is rated not rated sufficient to be compatible with the Paris Agreement long-term objectives) being met comfortably. This indicates that India may not need to support activities for captive biomass energy specifically in order to meet its NDC objectives; further mitigation through captive biomass energy may enable India to over achieve its NDC, although over-achievements in some areas could, in theory, lead to a decrease of efforts in other areas.

However, depending on the specific support measures utilised, it may be that measures supporting biomass IPP projects will also have a positive supporting influence on captive biomass energy projects.

Potential for perverse incentives in policy making

The use of biomass is promoted through several policies in India, such as feed-in tariffs (see above). This raises the question how these domestic polices interact with crediting programmes. The treatment of such policies, also referred to as E- policies under the CDM, has been debated controversially, in particular with regard to feed-in tariffs, where claims were made that they may have been lowered to ensure that projects still qualify under the CDM (Spalding-Fecher, 2013). Given that the promotion of biomass is a key priority in India and that policies are already in place, the possibility of crediting – if significant and with prices above current level – could have an impact on such policy development.

Programs to support biomass projects might be set up in ways to avoid such incentives, for example, by focussing on projects that do not qualify (any longer) for policies promoting the use of biomass. Another approach could be a sectoral results-based funding program where the donor supports directly the support of projects at risk through domestic policies, such as feed-in tariffs.

Transformational change potential of the activity

Using biomass from sustainable sources for energy generation is commonly considered one of the key pillars for long-term low emissions development strategies. Promoting the continued use of biomass could help biomass markets to mature and thus support this strategy. Continued use of biomass may also help avoiding a lock-in in fossil fuel fired power plants, since an enhanced biomass capacity may reduce the need for building new fossil fuel fired power plants. In long-term strategies for renewable power generation, a further advantage of biomass power is that biomass can be stored and more electricity may be generated at times when other renewable sources are not available; biomass power plants can help balance the fluctuations in electricity demand and supply. Finally, the use of biomass might have an even greater role in the future if negative global emissions may become necessary through biomass use in combination with capture and storage of CO_2.

An important issue is that the biomass is sourced from sustainable sources. CDM methodologies aim to ensure that either biomass residues are used or that it is originated from newly established dedicated plantations, with the view to ensuring that biomass supply increases as a result of the CDM project.

The potential for replication is likely significant in India, as the available information suggests that there are barriers for potential suppliers of biomass and more biomass could be supplied to the market. However, this situation could be different in other countries with more established biomass markets and higher scarcity of supply.

Using biomass for power generation has also significant potential for further innovation, through increases in power plant efficiencies or different routes to biomass use, such as gasification and use of the gas in more efficient combined cycle power plants.

Summary of mitigation impact

Biomass power generation is a priority for the government of India. Using biomass for energy generation could avoid lock-in in GHG intensive technologies and is generally considered an important pillar of long-term low emissions development strategies. At the same time, the direct emissions impact depends on the extent to which the biomass competes with other uses and biomass supply increases as a result of a policy program supporting existing projects. Moreover, a programme crediting biomass use could overlap with other policies to promote biomass use and might create perverse incentives for policy makers in pursuing other policies to promote biomass. Appropriate design of support policies is therefore important. This is further discussed in section 9.

8.5 Energy Efficient Cook Stoves in India and Kenya

Project discontinuation scenario

In section 7.3, the following discontinuation scenario was identified as the most likely scenario:

> *The newly installed clean cook stove continues to be used by the household until a defect occurs, at which point a cheaper, traditional stove is used as a replacement.*

This scenario is understood to fit the majority of projects, although it is understood that a small number of projects may continue because they may be operated by entities that are not motivated only by the financial benefits of the project.

Direct emission reduction potential

The global potential for emission reductions from clean cook stove projects is large. An estimated 2.7 billion people worldwide rely on traditional biomass – wood, charcoal, animal waste and agricultural residues – for cooking and space heating (Lambe & Atteridge, 2012). According to Bailis et al. (2015), emissions from wood fuels are 1.0–1.2 Gt CO_2e per year or 1.9–2.3 % of global emissions and approximately 275 million people live in wood fuel depletion 'hotspots' — concentrated in South Asia and East Africa — where most demand is unsustainable.

The projects analysed for this study included mostly those with the methodologies AMSI-II.G. – Energy efficiency measures in thermal applications of non-renewable biomass (small scale), and AMS-I.E. – Switch from non-renewable biomass for thermal applications by the user (small scale).For AMS-II.G. projects, the baseline of the CDM project methodology is defined as follows (UNFCCC, 2012):

> *Continuation of the current situation; i.e. use of non-renewable biomass as fuel for the existing, less-efficient thermal applications.*

For AMS-I.E. projects, the baseline of the CDM project methodology is defined as follows (UNFCCC, 2012):

> *Thermal energy would be produced by more-GHG-intensive means based on the use of non-renewable biomass.*

For both methodologies, the methodology baseline is considered equivalent in its outcome to the discontinuation scenario identified, after failure of the clean cook stove. The emission reduction potential from PDDs is taken as a basis for an estimation of the potential mitigation impact of the provision of support for continuation; this calculation indicates the maximum emission reduction potential assuming the failure of all clean cook stoves, forcing the use of traditional stoves as a replacement. Realistically, many cook stoves will continue to function correctly for several years: the cook stoves used in CDM projects are typically predicted to have an operating lifetime of 3-4 years due to either technological fault or poor usage practices. As such, the actual mitigation impact from supporting continuation will gradually increase up to the maximum identified here, as more stoves fail, but will be considerably lower in the first years.

The total of the average annual emission reductions predicted by PDDs for cook stove projects in India and Kenya is 0.53 M t CO_2e and 0.72 M t CO_2e, respectively. Only a very small proportion of cook stoves projects have issued credits, so it is not considered appropriate to adjust these figures according to issuance success rates.

However, several independent studies of cook stove projects have cast these potential emission reductions into doubt. For example although lab tests indicate an average 67 % reduction in fuel consumption from efficient cook stoves compared to traditional technologies, Aung et al (2016) find no significant statistical difference in fuel consumption between households with new efficient stoves and those with traditional stoves or open fires. Bailis et al. (2015) use a spatially explicit assessment of pan-tropical woodfuel supply and demand to calculate the degree to which wood fuel demand exceeds regrowth. While default values under the CDM typically assume that about 80-90 % of the woodfuel supply is unsustainable, Bailis et al. (2015) estimate that 27–34 % of woodfuel harvested was unsustainable and concludes that carbon offset projects are probably overstating the climate benefits of improved stoves.

Relationship between the activity and international climate pledges

India

The background of India's NDC mentions the existence of various programmes to enhance access to clean energy and energy efficiency, with reference specifically the reliance of the majority of the population on biomass energy. This reference includes energy for cooking stoves implicitly, but no specific targets are given in this regard. The only specific target in the NDC to cover household energy is the country's economy-wide emissions intensity target, to reduce emissions intensity of GDP by 33 to 35 percent by 2030 compared to the 2005 level (Government of India, 2015). The pledge under the Cancun Agreement also includes an emissions intensity target (20 to 25 percent reduction by 2020 compared to 2005).

It is understood that the majority of the plans for the achievement of this target will be based on measures for renewable electricity energy supply (see section 8.4 and CAT 2015), but India also stresses the importance of end use energy efficiency and has launched the Nationwide Campaign for Energy Conservation. It is unclear to what extent measures for household energy efficiency, including cooking, might be prioritised to meet the targets.

Kenya

Kenya's INDC includes an economy-wide emissions reduction target, along with key mitigation areas that the country intends to pursue to meet the target. One of these key measures is to improve access to clean energy technologies to reduce the over reliance on wood fuels (MENR, 2015); the National Climate Change Action Plan (NCCAP) to which the INDC refers, confirms that household cook stoves is one of six priority mitigation areas (Government of Kenya, 2013). As such, it is likely that cook stove projects would be prioritised for support in order to meet the target of Kenya's INDC. However, Kenya also makes it explicitly clear in the INDC that the target is reliant on international finance support, and cannot be met through domestic support channels alone. Kenya did not lodge an official pledge under the Cancun Agreements.

Potential for perverse incentives in policy making

As previously discussed, many countries already have policies promoting clean cook stoves in place, next to international initiatives to promote the use of clean cook stoves. Under the CDM, cooking stove projects are included in positive lists and baseline emissions are determined in relatively standardized ways, independent of policies in place in the sector. As long as cook stoves are included in the positive lists, the potential for crediting emission reductions would not be lowered if countries introduced policies to promote the use of more efficient cook stoves. Hence, there are no immediate perverse incentives for these countries not to introduce such policies. However, positive lists are updated in light of new developments. If the market penetration of clean cook stoves would increase in response to policies by the host country, clean cook stoves might be removed from the positive list in the future. This could theoretically create some disincentives for policy makers to introduce such policies.

On the other hand, the co-benefits from using clean cook stoves can be considerable. This may provide incentives for policy makers to support the use of clean cook stoves, regardless of the possibility to access international crediting.

Transformational change potential of the activity

Using low GHG technologies for cooking is an important element of long-term strategies for low carbon development. Given their limited use so far and the large number of people relying on fuelwood, large-scale deployment of clean cook stoves has considerable potential for replication. The risks for carbon lock-in are low, given the limited technical lifetime and relatively low costs of cook stove devices.

Clean cook stove projects can have particularly high co-benefits, including the reduction of indoor air pollution, of forest degradation and of deforestation. However, clean cook stove technologies vary with regard to their co-benefits; they may not always be realized, as shown in a case study in India (Aung et al., 2016). Furthermore, there is a risk of a potential mismatch between cheap and efficient technology and meeting user expectations and preferences (Lambe, Jürisoo, Lee, & Johnson, 2015).

Summary of mitigation impact

The promotion of clean cook stoves has a very large global emission reductions potential; emissions from wood fuels are estimated with 1.0-1.2 Gt CO_2e per year or 1.9-2.3 % of global emissions. Clean cook stoves could also provide considerable co-benefits. However, current CDM methodologies are likely to over-estimate emissions reductions and the extent to which co-benefits are achieved is uncertain. Programs supporting the continued use of clean cook stoves may thus carefully consider how emission reductions are quantified and how program design can ensure that that co-benefits are realized.

9 Policy Options for Continuing Mitigation of Vulnerable Projects

Our analysis in previous chapters showed that several project types have a significant abatement potential but are at risk of stopping GHG abatement. This chapter explores different policy options for ensuring that GHG abatement in these project types is continued.

The analysis includes the following project types, which were assessed in the previous sections to (a) have a high risk of project discontinuation (sections 5 to 7) and (b) to have the potential to reduce GHG emissions if their operation is continued (section 8):

- Commercial livestock manure management projects in Mexico and Brazil (High risk)
- Independent biomass power producer projects in India (High risk)
- Captive biomass energy projects in India (High risk)
- Energy efficient cooking stove projects in India and Kenya (High risk)

Policy options for supporting palm oil solid waste composting projects in Malaysia are not analysed in section 9. The analysis in section 8 found that in many instances there may not be a mitigation impact from supporting the continuation of composting projects, since approximately half of projects are considered likely to continue, whilst for the remaining half, the most plausible discontinuation scenario – sale of EFBs for other uses – may also entail a similar mitigation impact to the continuation of the project.

The analysis of biomass IPP projects and captive biomass energy projects in India is combined in section 9.3, due to the considerable overlap between options for these project types.

9.1 Approach for Assessing Policy Options for the Continuation of Project Activities

The scope of the assessment for this report focuses primarily on the projects within their specific country context, in line with the rest of the analysis in this study. However, the results of the assessment may offer insights for appropriate support instruments in other countries with similar conditions. The assessment provides initial insights into the potential policy options, based upon the findings from previous sections of this study. Overview of approach

The analysis of the support options proceeds as per the following steps:

Step 1 Recap on the barriers for the project continuation scenarios

Step 2 Evaluate the feasibility of potential supporting policies and measures

Step 3 Evaluate the potential of the policies and measures for cost-effective removal of the barriers

The following types of support measures are discussed, as illustrated in Table 50:

- International market based and carbon pricing measures
- Domestic market based and carbon pricing measures
- International support for domestic non-market based policies and measures

The list of potential policies and measures is drawn for this study from literature review and the insights of the authors, based on the analysis of the project types in other sections of the report.

Table 50: Examples of the types of potential support measures and policies evaluated

International market-based/ carbon pricing measures	Domestic market-based/carbon pricing measures	Other international support for domestic measures
▸ Enhanced/preferential demand for CERs (e.g. credit purchase facilities ▸ Alternative project level crediting programmes ▸ Sectoral crediting mechanisms (pilot)	▸ Domestic ETS (e.g. China) ▸ Domestic offsetting programmes ▸ CO_2 taxes	▸ Supported NAMAs ▸ Other results-based financing ▸ Direct financial support (grants/ loans) ▸ Technical assistance Examples of domestic measures: ▸ Standards and regulations ▸ Financial incentive instruments ▸ Capacity building ▸ Financial relief programmes ▸ Market / supply chain development

Description of international measures

Table 50 presents an example of the types of support measures assessed for each of the vulnerable project types. The relevant domestic market based and carbon pricing measures are variable for the different project types and countries, so are discussed in the individual sections. In general, the following international measures are evaluated for all project types:

- **Enhanced/preferential demand for CERs (e.g. credit purchase facilities, voluntary offsetting)**
  Purchase facilities might increase demand for credits from CDM projects and/or increase the sellable price of these credits, thereby encouraging CDM project owners to continue engagement in the mitigation activities. Credit purchase facilities can also be used for non-market climate finance in the case that credits are not used for compliance but are rather cancelled.
  For example, the Pilot Auction Facility (PAF) of the World Bank, backed by Germany, Sweden, Switzerland, and the United States, has used a reverse auction mechanism to purchase CER credits for methane avoidance projects, whilst both CERs and VCS credits for nitric acid projects will be targeted under the next auction period in 2017. Similarly, entities purchasing CERs for voluntary offsetting could prioritize project types that are at risk of stopping GHG abatement.
- **Alternative project level crediting programmes**
  Projects might deregister from the CDM to be registered in alternative crediting programmes, mostly for voluntary markets.
- **Scaled-up crediting programmes (S-CP)**
  Various terminologies and proposals have been used for scaled-up crediting instruments in past years, some commonly used ones being approaches to sectoral crediting, policy crediting, NAMA crediting etc. In essence, these proposals deliberate on either project/programme level instruments with more standardisation in baseline setting (sectoral crediting); or expanding the project based approaches to a sectoral level (i.e. up-scaled project-based crediting). Crediting instruments can have a voluntary or mandatory participation (Wang-Helmreich et al., n.d. forthcoming).

  Up-scaled project based crediting operates at a project level and covers specific mitigation activities. It standardises the baseline setting variables (e.g. emission factors) for the scheme participants. The generated credits are calculated at the level of individual projects.

  On the other hand, in ***sectoral crediting*** mechanisms, a crediting baseline may be set for a broad segment of economy in the host country. Coverage of a sectoral baseline could be a sector or a sub-sector and emission reduction credits are calculated at the sector level by comparing actual performance of the group as a whole, against the baseline. Credit revenues may be collected by a central governing authority for the sector, who could assume the role for optimum distribution of those benefits for implementation through policy instruments and support schemes that are incentive driven. Scaled-up approaches are not highly developed, there is no formal agreement for their usage in international accounting, and only a handful of pilot approaches are under development in the sectors of some countries, for demonstration and testing purposes.

The modalities of the approach as well as the specific baseline may be determined bilaterally or multilaterally.

- ***Other results based financing (RBF)***
  Results-based financing (RBF) is a modality of dispersing finance for projects or interventions conditional to the verified achievement of predefined objectives (Warnecke, Röser, Hänsel, & Höhne, 2015). The CDM is already an example of RBF, but RBF can be applied outside of carbon finance, based on any quantifiable results, dependant on the objectives of the intervention and the design of the finance conditions. RBF approaches are also being considered as part of the funding activities under the Green Climate Fund (GCF). RBF could also be administered as an alternative financing mechanism for sectoral crediting approaches.
- ***Supported nationally appropriate mitigation actions (NAMAs)***
  NAMAs could support a wide range of activities according to the barriers and sector needs. NAMAs can include specific activities, policies, programmes, or packages of measures which are usually supported by innovative financial mechanisms to leverage private sector finance. Existing NAMA concepts worldwide have often demonstrated potential to combine international and domestic resources to leverage private sector finance that targets specific barriers. If well designed, such an approach may combine the best of least-cost approaches.

Evaluation criteria

We assess the measures broadly with regard to the following criteria:

- **Practical feasibility**
  This includes practical considerations, such as institutional aspects, enforcement of policies, and transaction costs. For example, transaction costs of crediting instruments could be lower in the case of large point sources compared to dispersed units.
- **Potential of the policies and measures for cost-effective removal of the barriers**
  This refers the effectiveness of ensuring continued GHG abatement by addressing the barriers directly (environmental effectiveness), the cost-effectiveness of the policies and the distributional impacts or potential risks for adverse economic impacts (economic implications).

These elements are assessed in this study based primarily on the insights and findings obtained from the previous research steps, supported by literature review and other expert insight, where appropriate.

9.2 Commercial Livestock Manure Management in Mexico and Brazil

9.2.1 Barriers for continuation of the project activity

Section 5.2 found that the theoretical economic conditions for project continuation may be positive for projects using electricity for on-site consumption and even more positive for projects exporting electricity to the national grid. The barriers to commercial livestock manure management project continuation in Brazil and Mexico are not based on financial feasibility of ongoing operation, but rather the following barriers:

- Lack of technical knowledge and capacities to operate the equipment for biogas production, collection and electricity generation.
- Upfront capital availability for replacement of motors in the case of equipment failure.
- Difficulties establishing grid connections, for net metering or sale to the grid.

Furthermore, it was found that smaller farms were more likely to face these barriers, whilst larger operations may find themselves in a position to continue.

9.2.2 International market and carbon pricing measures

Practical feasibility of measures in Brazil and Mexico

Out of the 154 registered projects in Mexico and Brazil, 123 chose a single crediting period of 10 years which is not renewable. 103 of them were registered between 2004 and the end of 2007 and could thus not generate CERs in the years to come. This has implications for the feasibility of market based measures.

The practical feasibility of measures that require project level crediting – including ***credit purchase facilities, demand for CERs for voluntary offsetting*** or ***alternative mechanisms for crediting*** – is relatively low in the majority of cases for commercial manure management projects in Mexico and Brazil. The reactivation of previous CDM project owners and equipment operators through a revival of credit demand conditions is usually not possible, since the project owners for the large majority of projects in Mexico and Brazil were third party corporate entities which folded into administration several years previous (see Box 1 section 5.2.2). The CDM Executive Board is considering procedures that allow other project owners, such as the plant operators, to withdraw the participation of previous owners, such as third party corporate entities, if they ceased to exist or agree to their withdrawal. However, even in the case that project owners were able to be reactivated or other project owners were to continue the project, the large majority of projects will not be able to issue CERs on their current CDM registrations for much longer due to the frequently used single ten-year crediting period. The Pilot Auction Facility targets projects for methane avoidance, including from livestock manure management. However, the suitability of the Pilot Auction Facility for commercial livestock manure management in Mexico and Brazil, specifically, is limited by these two major barriers, and also the requirement to purchase put options in the auctioning process, which requires upfront capital beyond the capabilities of small farms, which are those that are most vulnerable. Furthermore, no commercial livestock manure management projects in Mexico or Brail are registered with any of the major labelling programmes such as Gold Standard, which would increase attractiveness of CERs for voluntary offset markets.

Mexico and Brazil do not have any dedicated national ***alternative project crediting programmes***, but international programmes may be available. Whether or not alternative mechanisms for crediting are a feasibility in reality is uncertain: for example, the VCS and GS-VER rules do not allow for a project that has been formerly registered under the CDM to claim credits beyond the total CDM crediting period[40], even in the unlikely case that the project owner could be reactivated. Furthermore, such processes would incur an administrative burden and costs in a market where well-known corporate failures have left little appetite for such investments and their risks. To date, there are no registered VCS or GS-VER projects for commercial livestock manure management in Brazil or Mexico.

For a small handful of projects, where it is still possible to re-mobilise the CDM project owners and where crediting periods may be longer, these practical barriers may not exist to the same extent. However, this small handful of projects are in most cases also the exceptional projects for which there is considerably less risk of discontinuation. As such, the practical feasibility for all international measures for project based crediting options is deemed to be low.

The situation might be quite different if existing CDM projects were ***included within a Programme of Activities (PoA)***. In this case, crediting would occur at the level of the coordinating and managing entity (CME) which might also be able to provide support for the correct utilisation of the mitigation equipment, thereby removing the major technical capacity barrier at the level of the individual project activity. However, the large majority of projects are standalone CDM projects and although the Executive Board is understood to be considering modes for increased flexibility in conversion of normal projects to PoAs, projects with expiring crediting periods would certainly not be eligible. As such, this would not be feasible for the very large majority of existing commercial livestock manure management projects in Mexico and Brazil.

The feasibility of support through a potential ***pilot sector-level crediting mechanism*** does not necessarily face the same barriers as project based crediting, if the mechanism would be implemented through policy and capacity building interventions that do not rely solely on project level entrepreneurship. Crediting would likely be handled by a single governmental entity and accounted for at the sectoral level against sectoral baselines, with only limited administrative burdens at the project level. Whilst project based crediting relies on entrepreneurship at the project level, sector based crediting mechanisms can be implemented at the policy level through interventions that address barriers other than, or in addition to, financial incentives. There are two potentially significant, but probably surmountable, feasibility barriers for such a mechanism:

- Whilst there has been a lot of discussion in recent years about sector based approaches, there is currently no internationally accepted blueprint for such mechanisms and the chances of such mechanisms coming into

40 This situation has been confirmed in a direct enquiry to the VCS secretariat in November 2016.

wide usage before 2020 is slim, even in the case that such a mechanism would be deemed by the international community to be an appropriate and accepted flexibility mechanism. Whilst this is all very uncertain, several initiatives are taking place worldwide to pilot sectoral crediting approaches, and a similar construct would offer some feasibility to this option.

- Since many manure management projects are at or nearing the end of their crediting period, the emission reductions of these projects may be included in sectoral baselines, despite the emission reductions not currently happening, although no such agreed rules yet exist. If this were the case, this could mean that the sector might have to achieve emission reductions equivalent to the value of the CDM project emission reductions before they are eligible to begin to generate credits for emission reductions beyond this. This would not necessarily represent an insurmountable barrier: not all farms potential livestock manure management sites were registered as CDM project activities, and policy-based implementation could address all activities across the sector with an impact on previous CDM activities and those that were never registered.

Potential of the measures for cost-effective removal of the barriers

A ***pilot sector-level crediting mechanism*** might have the flexibility to address several barriers. The finance available through the mechanism for enhanced action at the sector level may lead to the introduction of any combination of domestic policies and measures within the sector, depending on the needs. Furthermore, since such a mechanism would be implemented against a baseline for an entire sub-sector, successful implementation action would support not only CDM projects, but also similar non-CDM activities, of which there are hundreds within Mexico and Brazil. In this regard, a sectoral based crediting mechanism has a good potential for environmental effectiveness. In contrast, measures that target specific project activities only, such as credit purchase facilities and voluntary CER demand might not have such a transformative effect beyond those specific measures.

The inherent flexibility for implementation of action under sectoral crediting approaches means that the construct is generally considered to have the potential for high cost-effectiveness. Market forces should mean that stakeholders who stand to gain from the finance available through such a mechanism would ensure that the most effective combination of actions and support measures are implemented.In reality, whether or not the potential for cost effectiveness is realised depends upon how the mechanism is organised, i.e. whether the mechanisms provides incentives in ways that ensure that the most cost-effective implementation options are pursued: optimal courses for implementation are likely only in the case that the financial benefits of the mechanism, which in the case of crediting against a sector baseline would likely accumulate to central governing authorities, are equally spread amongst stakeholders, in particular amongst those who bear the costs for the implementation of action. A poor set up of the mechanisms could lead to pursuing inefficient options for implementation or possibly also to perverse incentives, which might have a detrimental impact on other potential economic activities, within or outside the sector.

9.2.3 Domestic market and carbon pricing measures

Description and practical feasibility of measures in Brazil and Mexico

The following domestic market based instruments could be enacted:

- ***Carbon taxation:*** carbon tax programmes place a price on emissions, or the carbon content of fuels. Such a taxation might incentivise anaerobic digestion. Such programmes are difficult and time consuming to establish, largely due to political barriers associated with resistance to increased taxation. Such a programme would also be difficult to enforce at smaller entities, such as small farms. As such, a carbon tax for farm emissions is not considered realistically feasible for developing countries in the period up to 2020. Mexico introduced a carbon tax in 2014 but the scope includes only CO_2 emissions from fossil fuel combustion for energy; expansion to other emissions sources such as methane avoidance in agriculture is theoretically possible but not feasible in the period before 2020, given the time required to design and introduce the carbon tax in its current form.
- ***Domestic carbon crediting & offsetting:*** Generally, crediting programmes could be established at the domestic level, issuing credits to projects that continue with emission reductions through anaerobic digestion, which could be sold as offsets to entities under the jurisdiction of a domestic ETS or carbon tax programme.

However, the feasibility of this approach for this project type in Brazil and Mexico is also very limited due to the small number of CDM projects that are still able to issue credits, both due to the expiration of a single ten year crediting period and the inability to reactivate CDM project owners who have moved out of the business entirely, as previously discussed. Under Mexico's carbon tax, emitters should be able to meet tax obligations through domestic offsets from CERs issued by CDM projects. However, the approach for using offsets for compliance with the carbon tax in Mexico is particularly complicated: rather than using CERs to offset the volume of taxable carbon, the scheme allows for the amount of the tax to be paid through the purchase of CERs, with the monetary offset value of the CERs set at the market value at the moment of paying off the tax. This provides no incentive for emitters to use CERs as a means of meeting tax obligations. The difficulty of the approach is perhaps reflected in the fact that two years after the entry of the carbon tax into force, the secondary regulation for the use of CERs has still not been passed (Wang-Helmreich et al., n.d. forthcoming).

- ***Renewable energy crediting/green certificates:*** programmes at the domestic level may issue credits to biogas renewable energy producers, which may in turn be sold to other electricity utilities to meet imposed requirements related to minimum targets for renewable energy production. Such types of programmes could provide a further revenue source for farms generating power from biogas produced through anaerobic digestion. REC programmes may offer some feasibility in Mexico and Brazil. REC programmes require a competitive pool of potential credit buyers (e.g. electricity distributors) to be successful; Mexico announced in 2015 that it plans to introduce Clean Energy Certificates (CELs – Certificados de Energia Limpia) by 2018 (Deloitte, 2015), although it is not yet clear what the requirements will be for certification and whether small scale biogas will be eligible. The feasibility of the programme also depends on the extent to which the planned privatisation of the Mexican energy sector is implemented in the coming years. REC programmes in combination with Renewable Purchase Obligations (RPOs) for electricity companies may also be feasible in Brazil, where there are a number of private and public electricity distribution companies, although without any plans currently in place, this is somewhat unfeasible before 2020.
- ***Nutrient crediting & trading:*** A small number of developed countries operate a cap and trading programme for nutrient loads in agricultural effluent. Farms may be covered directly under the cap and trade programme, or they may be eligible to produce credits for use as offsets in the programme. Incentives to optimise the nutrient load may, in turn, incentivise anaerobic digestion practices, which offer good control over the nutrient properties of effluent.
  However, nutrient load crediting is also considered unrealistic in Mexico and Brazil, as well as other developing countries; such programmes have been implemented only on a small scale in a small handful of developed countries and require very developed systems for monitoring and enforcement.

Potential of the measures for cost-effective removal of the barriers

Of the potential domestic market measures, only REC programmes were found to have a reasonable degree of feasibility in Mexico before 2020, whilst none of the identified domestic market approaches were seen to be feasible in Brazil in the very short term.

Since the assessment of the barriers for commercial livestock manure management projects finds that the financial attractiveness of the projects is not the barrier for their continuation, it might be considered that policies and measures to increase the level of financial attractiveness – including REC programmes – may not be very effective for supporting continuation, unless they are introduced together with general improvements in the enabling environment; further increasing the financial incentives of the activities may enact indirect forces to remove the barriers, but this does not address the major barriers directly.

9.2.4 International support for domestic measures

A global assessment of domestic policies to support manure management projects concluded that, whilst effective options are available and demonstrated in some countries, such policies and regulations are not yet widely applied in most countries (Teenstra et al., 2014).

While Mexico has demonstrated great enthusiasm for the development of NAMAs, with more registered NAMA concepts in the UNFCCC NAMA registry than any other Latin American country (UNFCCC, 2016b), no activity from Brazil in the development of NAMAs has been visible in recent years. As such, the likelihood of such an approach in Brazil with pre-2020 implementation being feasible is considered to be low.

For the international support options of NAMAs and various other RBF approaches, the economic implications can be potentially very positive but are entirely dependent on the specific activities conducted under the approaches and the means of their implementation. Since RBF approaches may be used as a mode of financing sector crediting approaches, the same arguments related to cost-effectiveness are true here as those discussed for sector crediting approaches in 9.2.2: RBF approaches could provide for higher cost-effectiveness in the case that the financial benefits are optimally distributed, but may lead to inequitable outcomes that do not maximise sustainable development objectives in the case that they are not. Safeguards are required to ensure optimal vertical distribution of benefits from such programmes. Since NAMAs can represent a combination of many types of activities, the cost effectiveness of such activities could be low or it could be high: however, existing NAMA concepts worldwide have often demonstrated potential to combine international and domestic resources to leverage private sector finance that targets specific barriers. If well designed, such an approach may be combine the best of least-cost approaches.

With regards to the domestic policy framework to achieve the emission reductions, different types of non-market-based policies may be implemented. Potential policies are identified and briefly discussed based on the insights from this study. A full analysis of promising measures is beyond the scope of the study but should be conducted for the detailed design of international support options. The following list includes discussion on the feasibility of domestic measures as well as their economic effectiveness for barrier removal.

Practical feasibility of domestic measures in Mexico and Brazil

- ***Standards related to agriculture and environment,*** including for air emissions, water emissions, manure storage and nutrient management practices, do not require implementing anaerobic digestion directly. However, continuation of the activities undertaken under the CDM project would allow better control over the parameters to meet these standards. Most developed countries enforce most of these standards (GMI, 2014), and some of the more basic standards such as for water emissions are also in place in some developing countries including Brazil and Mexico. New standards to include nutrient management or air emissions face difficulties due to the MRV and enforcement frameworks required, which are considerably more complex than the equivalent requirements for water effluent emissions. However, both Mexico and Brazil are rapidly developing countries with greater capacities than most countries in the region, and it might be expected that they would show regional leadership in following global best practice with regards to agricultural standards in the medium-term.
  Whether or not it is feasible to enforce such standards at small farm sites in the period before 2020 is uncertain, partly due to the challenges associated with enforcement over such a large number of distributed activities, and partly due to the difficulties that project activities would face in compliance without further supporting instruments, due to the barriers discussed in this study. As such, the feasibility of new or strengthened standards is considered to have relatively low feasibility for small farm sites before 2020 if implemented in isolation of other policies and measures, but should probably form an integral component of policy packages in the near future.
- ***Streamlining of bureaucratic procedures for grid connectivity:*** whilst grid connection is, in theory, possible in Mexico and Brazil through net metering schemes, it was reported that projects face extremely long delays and obstructive bureaucratic procedures in the establishment of such connections. Assuming political will, there should be no insurmountable barriers to the revision and streamlining of such procedures.
- ***Renewable energy support schemes*** such as preferential feed-in tariffs and tax exemptions can provide further economic incentive for farmers for the continuation of the activity. Tax exemptions related to renewable energy production already exist to a certain extent in both Mexico and Brazil (KPMG, 2015), but both countries could benefit from the development of higher incentive renewable energy support schemes to meet their renewable energy targets.
- ***Financing programmes*** such as subsidies and microcredit programmes may address barriers related to lack of capital for replacement motors. Micro-credit programmes such as revolving loan funds exist in rural areas of Brazil and Mexico in other contexts, and should therefore also be practically feasible.
- ***Capacity building*** through awareness raising and training programmes, perhaps delivered through agricultural extension services, could address the barriers related to technical knowledge for operation of mitigation equipment at the project level, and awareness of the benefits.

Capacity building in the agriculture sector is often well established for various objectives related to agricultural efficiency, and increasingly also objectives related to environmental issues, due to the collective incentives of these practices for private entities along the input and output supply chains as well as for shared objectives of local governance.

Potential of the measures for cost-effective removal of the barriers

The development of new or tougher standards, in particular ***standards for air emissions from farms,*** can have high environment effectiveness, depending on several factors. If the emission standards are set at a level which are tough enough to require controlled digestion of manure and capture of biogas, if it is realistically possible for farmers to comply with the standards, and if the standards are strictly enforced, then the environmental effectiveness of such an intervention would be very high. Whilst this high environmental effectiveness could be expected from the medium-term, the enabling conditions must first be laid; none of these conditions are likely to prevail in the period before 2020, unless such standards are implemented alongside a suite of other supporting measures that address the barriers to continuation directly. Even if the standards are set at a stringent level, famers will face significant compliance difficulties in the short term, and enforcement will be challenging; currently, the stringency of enforcement of more basic existing standards for the livestock sector is assessed to be poor in Brazil, also the potential for effective enforcement may be greater in Mexico (Teenstra et al., 2014). The cost effectiveness and economic implications of such measures is entirely dependent on the suitability of the enabling conditions for compliance. In the case that the conditions are conducive for compliance and that the burdens of enforcement can be limited or shared amongst other activities, cost effectiveness may be high. However, in the context of the pre-2020 situation for Mexico and Brazil, the implementation of such standards in isolation would not be cost effective for farmers of for regulators: farmers would face the brunt of barrier removal costs, which could be much more efficiently assumed by the private sector through other measures, whilst the cost of enforcement for regulators is likely to be considerably higher than the cost of interventions that provide natural incentives for the desired practices. A positive economic implication for such standards, if used alongside other interventions, is that they provide a signal to stakeholders including the private sector, increasing the long-term certainty and removing the risk for private sector investment in barrier removal.

The ***removal of bureaucratic barriers for grid connectivity*** is considered to be a relatively low cost measure (Garbe, Latour, & Sonvilla, 2012), requiring only additional administrative resources. There are no obvious risks of adverse impacts, but clear potential for major economic gain across the energy sector as a whole, by reducing the transaction costs of electricity supply. Taking such measures holds important synergies with wider objectives for increased privatisation and competition within the energy supply sector in Mexico and Brazil. Since they do not directly address the major barriers to project continuation, policies and measures that increase the level of financial attractiveness, such as ***renewable energy support schemes***, may not be very effective for supporting continuation directly. On the other hand, the introduction of feed-in tariffs, in addition to further increasing the financial incentive for the activity, provides an opportunity for establishing new and streamlined administrative procedures for grid connection for eligible electricity producers, which would tackle one of the major barriers directly, and may likely entail synergies that cause the impacts of the measures combined to be greater than the sum of their potential impact individually. There is considerable debate on the economic appropriateness and cost-effectiveness of FITs in Mexico and Brazil – as well as many other countries generally – compared to other options for encouraging the development of renewables. In the case of Mexico and Brazil, the cost effectiveness of FITs for electricity from commercial livestock manure management might be considered low, given that the financial attractiveness of the emission reduction activity is found to be good even in the absence of such an instrument.

Especially for smaller farms, ***micro-credit options*** may have great potential for barrier removal and may have the potential for high environmental effectiveness. Subsidies, unless being great enough to cover the majority of the cost, will not adjust the barrier, since the issue is not about adjusting the costs to make the activity financially attractive, but rather just about making the upfront costs of a readily attractive option affordable for small scale farmers who prefer to prioritise their investments elsewhere. Micro-credit options, which can reduce the costs variably according to the conditions of the individual farmer and what they are willing to pay, may successfully overcome this barrier and the environmental effectiveness is therefore considered to be potentially high. Whilst many small farms would not be worthy for formal credit usually, such services could be offered by suppliers of agricultural inputs, where similar programmes are often successfully implemented due to the personal familiarity of the actors and their inter-dependence.

The cost effectiveness of microcredit schemes is understood to be high, since the benefits for overcoming the barriers are potentially large, whilst the costs for programme administration can often be shared across similar existing rural microcredit programmes, and the costs for capital finance are entirely internalised and covered by the economic gains of the private activity. Such programmes would avoid the issue of opportunity cost, whereby the farm owner might forego the opportunity to use their own scarce capital to invest in other areas of the business.

Capacity building might have a particularly strong impact on the feasibility of project continuation and on mitigation outcomes since technical capacity at the project level was identified as the major barrier for continuation. The costs of such measures can be manageable in the agriculture sector through the use of existing supply chains and agricultural extension services. Building capacities for the technical operation of mitigation equipment would entail costs, but these costs can be minimised or shared if delivered alongside other agricultural capacity building exercises. Costs may be internalised if such measures also deliver results on other programmes and objectives, for example on potential objectives to increase the proportion of skilled labour in rural areas, or objectives to develop rural supply chains for electrical components. Such objectives could be held by private as well as public entities, so it might be expected that there is a role for the private sector in picking up the costs of such measures.

9.2.5 Summary of support options for commercial livestock manure management

The findings indicate that the greatest need for support for commercial livestock manure management projects in Mexico and Brazil is probably through capacity building, technical assistance, bureaucratic barrier removal and availability of affordable small scale credit, rather than the new provision of major capital flows. Table 51 presents a summary of the support options for commercial livestock manure management projects.

The potential for established international market based approaches is probably very limited, mostly due to the inability of most projects to continue to issue CERs due to their single ten-year crediting period, but also due to the inability to reactivate original third party CDM project owners and administrators, who have moved away from the business in most cases.

A pilot sectoral crediting approach based on sector level benchmarks and implementation through policies could offer an option, and could be financed either through an international market based mechanism or through non-market results based financing. These approaches are not at a highly-developed stage at the national or international level; only a pilot approach would be feasible before 2020, and the effectiveness of such approaches is uncertain, although the flexibility of the approach leaves high potential for implementation through the most efficient activities. Such an approach could potentially have a large impact due to the ability to affect both registered CDM projects and similar non-CDM activities in the sector, which may also be addressed by sector wide policy measures.

From the perspective of other international instruments, there are indications that the development of a supported NAMA could be an effective means of implementing key domestic measures, particularly in Mexico where several ministries have developed significant experience with NAMA development. For example, an internationally supported NAMA could involve technical support elements for the redevelopment of grid connection regulations, whilst supporting the development of innovative mechanisms that leverage the private sector for both capacity building exercises and the provision of capital for micro-finance.

From the available domestic measures, the findings from this study indicate that the following options may be the most promising in terms of their feasibility, environmental effectiveness and economic implications:

- Awareness and training programmes could begin to address the major barrier in Mexico and Brazil which is the limited capacity and technological know-how for operation of the mitigation and electricity generation equipment.
- Microcredit programmes could play a role to address the barrier related to the availability of capital for small motor replacements, where traditional and more formalised finance channels do not offer any potential.

Training programmes and microcredit programmes could, for example, be implemented through existing or new agricultural extension services to build on the links, trust and efficiencies of these existing community networks.

- Streamlining bureaucratic procedures for grid connection will increase the feasibility for more projects to pursue the most economically attractive continuation scenario which was found to be the sale of electricity from biogas to the grid. This could increase the financial attractiveness of the mitigation by such a significant extent that solutions to other barriers may be driven by market forces.

Such measures might also have a far wider transformational impact in the sector beyond already registered CDM projects; it is understood that there are hundreds of similar commercial livestock manure management activities in Brazil and Mexico which have not registered under the CDM, but yet face the same barriers to the uptake of emission reduction technologies which would be highly profitable for them. Furthermore, the operating models of these mitigation activities are financially profitable without public or international financial support, so the continuation of these activities could be expected in the long term, as long as the enabling conditions remain conducive.

Table 51: Summary of potential policy options for commercial livestock manure management projects in Brazil and Mexico

Policy / measure	Policy assessment for Mexico		Policy assessment Brazil		Barrier addressed
	Practical feasibility	Barrier removal effectiveness	Practical feasibility	Barrier removal effectiveness	
Market and carbon pricing based measures					
International					
CER demand through credit purchase facilities or for vol. offsets	×	n.a.	×	n.a.	-
Alt. crediting programmes	×	n.a.	×	n.a.	-
Pilot sector-level crediting	•	•	•	•	Potentially all
Domestic					
GHG taxation	×	n.a.	×	n.a.	
Domestic offsetting	×	n.a.	×	n.a.	
Renewable energy certificates	✓	×	×	n.a.	-
Nutrient crediting and trading	×	n.a.	×	n.a.	-
Domestic non-market measures (e.g. with international support through NAMAs or RBF)					
Agric. & env. standards	•	•	•	×	-
Streamlining grid connectivity	✓	✓	✓	✓	Connectivity
RE support schemes	✓	×	✓	×	None directly
Micro-credit	✓	✓	✓	✓	Capital
Capacity building	✓	✓	✓	✓	Capacity

Source: Authors' own elaboration based on findings from the study
Green and red refer to positive and negative conditions, respectively. Yellow is used where the conditions are highly uncertain or highly variable according to specific circumstances.
Where one element is found to have negative conditions, the following aspects are not considered (noted n.a.).

9.3 Captive Biomass Energy and Biomass IPPs in India

This section includes an overview of policy options for both captive biomass energy projects and biomass IPPs in India. The barriers for the continuation of both project types are similar and there are considerable overlaps for the support options.

Section 8 explained that the mitigation impact from supporting biomass projects in India was regionally variable and unclear, depending upon the potential in the region to supply more biomass to the market and the extent to which the biomass would otherwise be used by competing users, which might also reduce greenhouse gas emissions. Nevertheless, this section identifies potential support measures for independent power producers, in the case that such support is considered appropriate for mitigation or other objectives.

9.3.1 Barriers for continuation

Sections 6.3 and 6.4 found that the major barriers for captive energy and IPP projects in India were similar. Like for their mitigation impact, the existence of these barriers and the risk of discontinuation is also regionally variable. It is understood from the findings of this study that the majority of projects are subject to the following barriers:

- The price of biomass, while highly variable, is usually too high to compete with coal for captive energy projects, and too high in most cases to justify the generation and sale of electricity, based on the tariffs.
- Biomass supply is, in many areas, volatile and unreliable due to the informality and immaturity of the biomass supply market. For captive energy uses in industry, volatile energy supply is a condition which entails enormous risks for the successful operation of the main economic activity of the industrial facility. For IPPs, unreliable supply undermines the business model, reducing revenues while sometimes incurring extra costs (e.g. for covering generation shortfalls through spot market electricity purchase.)

9.3.2 International market and carbon pricing measures

Practical feasibility of measures in India

- Increasing the demand for preferential purchase of CDM credits, for example through ***credit purchase facilities*** or ***demand for voluntary offsetting*** is feasible, since projects are usually somewhat bigger and have greater capacities to meet requirements of purchase facilities than some other project types, such as small scale commercial livestock manure management projects, whilst the original CDM project owners are usually still active and potentially available to continue verification and issuance cycles.
  An example of such a voluntary offsetting programme is the German Government's commitment to offset all business trips, for which it purchased CDM credits from five projects, including one biomass IPP project in India (DEHSt, 2016). Several Indian biomass energy projects are already registered with the Gold Standard, a labelling programme which makes CERs more attractive to voluntary purchasers.
- ***Alternative voluntary emission trading schemes*** would require re-registration under another programme or the conversion of CERs to VERs under a separate programme. While these procedures are in some cases relatively simplified, they do incur costs, and voluntary VER credits do not open up any new additional markets in India compared to the continued issuance of CERs with labels such as the Gold Standard.
- ***Sector-level crediting mechanisms*** as a concept do not yet exist on any significant scale, and are unlikely to be realised before 2020. The only feasible option would be the introduction of a pilot sector based crediting mechanism. Although a sector based approach would be practically feasible for the energy sector of India in general, this specific sector and country combination is not realistically feasible for a pilot mechanism, due to the very large size of the Indian energy and industry sectors, and the very large number of entities and emission sources. Sector-level crediting is untested and unproven, and it is not yet well understood how such an approach can exist alongside other domestic policies and measures, and what impacts it may have in the sector or the wider economy. Pilot sector mechanisms would be better applied to more contained testing grounds, such small or medium scale sectors with a finite and manageable number of active entities, where it might be feasible to generate sufficient finance/demand, and where the risk of lock-in to non-optimised first approaches does not have such a large impact. In theory, such an approach may be slightly more feasible in the Indian energy sector is restricted to individual states, although this would not be address the majority of the CDM projects under discussion, which are dispersed around the country.

Potential of the measures for cost-effective removal of the barriers

Increasing the demand for preferential purchase of CDM credits, through credit purchase facilities or ***demand for voluntary offsetting***, may increase the financial attractiveness for the continued use of biomass at captive energy industries and IPPs. Whether or not the increased financial benefits could address both of the major barriers is unclear.

For both captive energy and IPP projects, increased demand for CERs at preferential prices could effectively address the barrier related to the fuel price by making the use of biomass more financially attractive than the use of coal. This depends upon the price level at which CERs are purchased. Purchase facilities can buy credits through bidding procedures and auctioning mechanisms that, in theory, could cost effectively target the continuation of the most competitive CDM projects.

However, it is unclear whether targeting the financial attractiveness of specific projects through enhanced CER demand will have a major impact on the other major barrier: the volatility and unreliability of the biomass supply market. For captive energy projects, it was reported that biomass utilisation was too risky even in the theoretical case that biomass would be by far the cheaper fuel, because of the greater risk of production outages. For these projects, revenues from preferential enhanced CER sales will not completely offset this risk. It is clear that part of the supply chain irregularities could be improved through market forces in the case that incentives caused a critical mass of sustained high value demand, but the typical industrial facilities have little incentive to do this in the current prevailing biomass conditions, since such a move would come at great risk to their business. For the small handful of projects where long term biomass supply has been guaranteed through reliable contracts or mutual agreements, this barrier would not be an issue, but these are not the projects with the highest risk of discontinuation. In general, the ability of enhanced preferential CER demand to encourage the continuation of captive energy projects is limited without complementary policies and measures addressed at the supply chain. Since such measures may have the potential to address both major barriers simultaneously, the cost-effectiveness of enhanced CER demand to address any of the barriers for these projects could be questionable. However, the conditions of projects vary considerably according to the specific industry and the local biomass supply markets, so it may be the case that enhanced CER demand, when implemented alongside measures that target improved supply chain conditions, may play a major role for barrier removal in some projects, whilst being irrelevant for others. Whilst for captive energy projects, the biomass market unreliability is considered the most important barrier, for IPP projects, the risks associated with this barrier are sometimes more manageable: although supply outages also incur a cease in the operation of the business, as they do for industrial captive energy projects, the economic consequences of such outrages may not be so great. Captive energy projects are attached to industries for which a stop of production due to unavailability of biomass could cause major economic losses. The potential long-term consequences of production outages can lead to cancelled contracts, and consumer dissatisfaction which could ultimately put the facility out of business.

By contrast, IPPs may incur some loss during times when generation is not possible, and penalties may be incurred from the purchasing electricity distributor (e.g. power plants are often required to make up shortfalls through spot market purchases), but the economic consequences are not as great as for captive users. For IPPs, enhanced revenues through CER sales may not immediately address the market supply issues in the short term, but depending on the price of the CER purchase the costs associated with this barrier might be offset; the equivalent impact is more unlikely for captive energy projects.

9.3.3 Domestic market and carbon pricing measures

Options for mandatory domestic emissions trading for biomass projects in India are currently limited:

- Biomass captive energy projects could economically benefit from the introduction of an ETS. With an ETS, using coal could become effectively costlier, therefore improving the economic conditions for captive users to use biomass rather than coal. For IPPs, an ETS could have the impact to make biomass more competitive with fossil fuel based power producers, although this would not have a direct impact in the Indian context since the feasibility of biomass projects is dependent on the feasibility of operating under the biomass feed-in tariff, rather than competitiveness with considerably less expensive coal power. India established a pilot ETS in three states in 2011, but this programme covers only local air pollutants, rather than carbon dioxide emissions (TERI, 2016).

Generally, there has been limited enthusiasm for a more comprehensive ETS in India, and it is considered unlikely that a wide reaching ETS could be approved, established and functioning before 2020.

- The potential use of CDM credits for ***domestic offsetting*** of mandatory targets in India is currently limited, due to the lack of mandatory emission caps for entities in India, and the lack of feasibility of an ETS programme before 2020; if an ETS were to be feasible before 2020 then the energy sector, including these projects, would likely be amongst the first entities to be covered. Many industries have their energy consumption capped through the Perform, Achieve, Trade (PAT) programme, but the PAT programme includes targets only for energy intensity and not for CO_2 emissions directly.

For other potential market based approaches for biomass in India, feasibility of the approaches is mixed:

- A ***Renewable Energy Certificates (REC)*** programme already exists in India. Currently, the feasibility of RECs for CDM projects is limited; most biomass CDM projects have PPAs in place for preferential tariffs and are therefore not eligible for the REC programme (IETA, 2015). For this to be feasible, changes would have to be made to the REC programme to afford eligibility to entities that still operate their biomass power generation equipment but agree to give up their preferential PPAs. This measure is also relevant for some captive energy projects, although current regulations state that only facilities constructed between the years of 2011 and 2015, which registered to the central agency of the REC scheme during this time are eligible. These conditions make most if not all captive energy CDM projects ineligible. Since this regulation was adjusted as recently as 2016, it is unlikely that it will be changed in time for effective implementation before 2020.
- India does not have a formal ***carbon tax,*** although there is a tax on domestic and imported coal, which has a similar effect to a carbon tax. The tax on coal is set to double to INR 400 (ca. USD 6) per tonne in 2017 (Clean Technica, 2016). A coal tax may, in theory, mitigate both major barriers in the case that the price was high enough and effectively enforced: the price of biomass would become more competitive with coal for individual CDM projects, and the higher cost of coal may create incentives for all energy generating activities across the entire economy, not only CDM projects, to invest in alternative fuels, including supply chains for biomass.
  However, the current tax level and the doubling of the coal tax rate in 2017 will increase the cost of coal only incrementally: assuming all other variables remain constant then the landed price of the most expensive coal would increase by just over 5 %; biomass per calorific value would remain approximately 50 % more expensive than the most expensive coal, unless the supply and price of biomass would be optimised to come in line with the initial cost estimates of project PDDs, which in some cases estimated biomass costs to be 2 or 3 times lower than the current average market price (see section 6.4.4). Increasing the coal tax could be a feasible measure for making biomass more competitive. Given that the coal tax has been successfully doubled three times since its introduction in 2011, further increases may be feasible, although India remains highly dependent on coal for its growing economy and it is unclear whether there would be enough political and industry support to a highly significant level in the near future. Indeed, the current coal tax may be significantly undermined by a suite of subsidies to the fossil fuel sector; subsidies for coal in India include direct funding for exploration and extraction as well as tax breaks for plant operation (ODI, 2015). This measure would be mostly relevant for captive energy projects, although could also have an impact for IPPs if the increased price of coal would lead to increased prices for coal fired power and subsequently increased tariffs for biomass energy.

9.3.4 International support for domestic measures

The development of NAMAs for implementation before 2020 is unlikely in India; the country has not demonstrated great enthusiasm for engagement in NAMA development and has no NAMA concepts registered at the NAMA database or the UNFCCC NAMA registry (NAMA Database, 2015; UNFCCC, 2016b).

Several non-market-based policy measures could be enacted to support IPPs at the domestic level. These could be split between policies that incentivise biomass utilisation for electricity, and policies which promote further supply of biomass. Potential policies are identified and briefly discussed based on the insights from this study.:

- Policies that target biomass utilisation can increase the financial attractiveness of utilising biomass for energy production for IPPs:

- ***Feed-in tariffs (FIT):*** whilst FITs are already in place in India, the tariffs could be increased to increase the financial benefits of electricity generation for IPPs. Stakeholders from the industry have produced argumentation to the CERC for why the current recommended tariffs do not reflect the real costs of biomass electricity generation (CERC, 2015).
- ***Tax exemptions:*** sales tax exemptions for electricity sales can decrease the costs associated with the business model for IPPs. Such a tax exemption does not exist in India, but does exist in several countries (KPMG, 2015).

These measures may play a role in making the cost of biomass electricity production more competitive against coal, and as such can remove one of the major barriers. These kinds of renewable energy support schemes may have long term potential; the financial support can be gradually phased out as the technologies and practices mature and become less reliant on the financial support. However, tax exemptions are extended at the direct expense of the national budget without direct private sector leverage, whilst increased preferential FITs may create a short term economic burden on the part of the electricity distributor.

- Policies for biomass supply chain optimisation, could address both major barriers by reducing the price of biomass by: a) creating extra supply and reducing transaction costs, and b) reducing the volatility and unreliability of the market:
  - ***Financial incentives for commercial distribution networks:*** subsidies and tax incentives can be used to encourage the establishment of facilities such as local collection centres and storage facilities, as well as to require their consistent operation. Incentives for commercial operations based on local entrepreneurship could leverage private finance forfor greater long term cost effectiveness, since financial incentives can be eventually phased out as private operations mature to become entirely self-reliant.
  - ***Municipal provision or incentives for fuel supply merchants:*** Fuel supply risks from competing markets for the biomass can be overcome by negotiation of appropriate contracts and forward sales agreements. However, many biomass fuel suppliers are farmers who are not familiar with long-term contracts.
    Fuel supply merchants who are experts in the development of contracts for fuel supply stakeholders may be required until markets and practices are more matured. Incentives could be provided for commercial distribution networks to play this role, or such agents might be provided directly by municipal budgets. In either construction, provisions should be made to ensure that such services can be phased out when market participants have enough experience and security to operate without the third parties, in order to reduce long term transaction costs.
  - ***Conditionality of subsidies for biomass producers:*** subsidies that are offered to farmers for various farming operations may be made conditional on the utilisation or sale of the use of biomass residues, to ensure that such residues reach the market.
  - ***Awareness raising activities*** could be carried out, potentially through agricultural extension services, to increase awareness of the potential markets for biomass sales, encouraging more potential biomass suppliers to join formalised markets. Whilst some awareness activities are conducted by UNFCCC Regional Collaboration Centres, these initiatives are usually targeted at existing or potential project participants, and would not address supply chain actors directly.
  - ***Further research in biomass potential and demand:*** One of the major challenges for investment decisions on biomass utilisation is the reliability of estimates on resource availability. Not all biomass can be collected for energy generation due to existing uses for traditional practices (cattle fodder, cooking, thatching, land manure) or for new non-energy related biomass demand markets. The major sources of information on biomass potential, such as the information provided by the Ministry of New and Renewable Energy (MNRW) or the Biomass Atlas is aging and there is a need to update these resource assessment databases, as well as to improve information on potential demand.
  - ***Investments/incentives in practices for palletisation:*** practices for biomass transport, such as palletisation, has decreased the costs and increased the efficiency of biomass supply chains in many developed countries. This measure is less likely to be a policy instrument and more likely to be funded by the private sector in the case that there are financial incentives for the development of the supply chain.

There may be a great deal of overlap between these measures and it is difficult to assess the cost effectiveness of each of the measures individually. For example, whilst the findings of the study point towards the impression that improvements in the reliability and formalisation of the biomass market may be most important for removal of barriers, these changes may be affected by regulations and financial incentives that target them directly, or they may be affected through natural market forces in the case that incentives for biomass utilisation are large enough to increase the weight and value of the market demand. For example, greater feed-in tariffs will increase the prices that demand side participants are willing to pay for biomass, possibly creating a more significant market for potential commercial fuel supply and distribution companies. Such measures are likely to be cost effective since preferential FITs can be easily phased out after several years once the major investments for the formalisation and optimisation of the biomass supply market have been carried out.

9.3.5 Summary of support options for biomass in India

Solutions to mitigate the risk of project discontinuation for biomass energy projects in India usually depend upon the removal of barriers related both to the economic cost of energy generation with biomass compared to coal, as well as the unreliability of the biomass market supply chain. Table 52 provides an overview of the potential market and non-market based support options.

For captive energy projects, measures that directly support the development of the biomass supply market are paramount. Policies that improve the economic feasibility of biomass over coal – such as enhancing CER demand through purchase facilities or voluntary offsetting, feed-in tariffs, the RECs scheme, the coal tax or the introduction of an ETS – may provide some incentives to overcome both barriers, but may not be sufficient alone.

For IPPs, it is more feasible that instruments targeting the economic feasibility of biomass use could address both major barriers directly, since there is the possibility in this case that the economic benefits from these instruments may help to overcome the barriers and risks associated with the unreliable biomass supply. In any case, complementary incentives targeted at the biomass supply chain directly would likely to also be effective, especially in the cases where the risks associated with the volatile market remain too great to be overcome by instruments that only provide economic incentives. Furthermore, since policies applicable to the wider industry such as feed-in tariffs willwill have an impact on many potential activities and not only existing CDM projects, it may create an increased mass of demand for biomass, which while putting upwards pressure on biomass prices in the short term, will encourage the development of the market and the lowering of biomass prices in the medium term.

Table 52: Summary of potential policy options for biomass projects in India

Policy / measure	Policy assessment for IPPs: Practical feasibility	Policy assessment for IPPs: Barrier removal effectiveness	Policy assessment for captive energy: Practical feasibility	Policy assessment for captive energy: Barrier removal effectiveness	Barrier directly addressed
Market and carbon pricing based measures					
International					
CER demand through credit purchase facilities or for vol. offsets	✓	•	✓	•	Costs
Alt. crediting programmes	×	n.a.	×	n.a.	-
Pilot sector-level crediting	×	n.a.	×	n.a.	-
Domestic					
GHG / fossil fuel taxation	×	n.a.	•	•	Costs
Domestic offsetting	×	n.a.	×	n.a.	-
Renewable energy certificates	×	n.a.	×	n.a.	-
Domestic non-market measures (e.g. with international support through RBF)					
RE support schemes (e.g. FIT)	✓	✓	×	n.a.	Costs
Biomass supply support schemes	✓	✓	✓	✓	Supply chain

Source: Authors' own elaboration based on findings from the study

Green and red refer to positive and negative conditions, respectively. Yellow is used where the conditions are highly uncertain, highly variable according to specific circumstances or where the measure may be effective only when used with complementary measures. Where one element is found to have negative conditions, the following aspects are not considered (noted n.a.).

9.4 Cook Stove Projects in India and Kenya

A recent review of the state of the global clean and improved cook stove sector found that 'while the challenges are daunting, there are now good reasons to believe that the next decade will be a transformative period for the global clean and improved cook stove sector' (World Bank, 2015d). With the emergence of aspirational middle classes, rapid urbanization and rising fuel prices there is a growing trend amongst consumers worldwide to seek more efficient fuels and stoves. At the same time, technological innovations and the development of new distribution and financing models have increased the supply of more efficient fuels and stoves. National policies to support the deployment of clean cook stoves, in combination with initiatives such as the Global Alliance for Clean Cookstoves are beginning to transform the clean and improved cook stove sector (World Bank, 2015d).

9.4.1 Barriers for continuation of the project activity

Section 7.3 found that continuation scenarios could be attractive in theory, but are subject to major barriers:

Continuation scenario C1: The newly installed clean cook stove continues to be used as long as it is working. Once the newly installed clean cook stove is broken, a similar new cook stove is bought at the expense of **the CDM project owner.**

- The project owner usually has no incentives to engage with the project without CER revenues, and would therefore usually have no incentives to replace faulty cook stoves.

Continuation scenario C2: The newly installed clean cook stove continues to be used as long as it is working. Once the newly installed clean cook stove is broken, a similar new cook stove is bought at the expense of **the household.**

- Households usually do not have the capital available to invest in the upfront costs for replacement stoves, which are considerably more expensive than traditional solutions, even in the case that benefits related to potential fuel cost savings and air quality impacts are perceived.
- Awareness on the optimal use of efficient cook stoves and the benefits of their use is limited amongst households.
- Linked to the previous barrier, there remain preferences in some cases for use of the traditional cooking options due to their better suitability for certain foods or due to cultural preferences.

9.4.2 International market and carbon pricing measures

Practical feasibility of measures in India and Kenya

- Increasing the demand for preferential purchase of CDM credits, for example through ***credit purchase facilities*** or ***demand for voluntary offsetting*** is feasible. Most projects in Kenya have crediting periods of 7 years, making them theoretically eligible for a second crediting period of 7 years. Most projects in India have crediting periods of 10 years, although all of these projects started their crediting period between 2011 and 2013 and could therefore issue credits up to beyond 2020. Project owners are also understood to be available to continue activities in many cases, even where the activity has stopped. Cook stove projects account for a considerable amount of the market for voluntary offsetting. Most of these projects remain registered with the CDM, seek registration under the Gold Standard label and then either sell their CERs or have their CDM-issued CERs officially converted to VERs under the Gold Standard. Another option is to convert the CDM registration to a GS-VER registration and to issue VERs under the Gold Standard directly (see alternative crediting mechanisms, below). In 2015, the average price of voluntary offsets from cook stove projects was USD 4.9 which, whilst far higher than the spot market price for CERs, represents an all-time low for voluntary offsets (Hamrick & Goldstein, 2016), and is somewhat lower than the estimated requirements for the continuation of cook stove projects (Lee, Chandler, Lazarus, & Johnson, 2013). This average price is also considerably higher than that of other project types, such as wind energy, but buyers are attracted to the high potential for non-climate related benefits (Hamrick & Goldstein, 2016). In total voluntary offsets for cook stoves accounting for 3.1 M t CO_2e were purchased through the voluntary market in 2015, with much of this coming from Kenya; cook stove projects provided the 5th greatest supply of credits to the voluntary market (Hamrick & Goldstein, 2016).
- ***Alternative crediting mechanisms*** including voluntary standards such as Verified Carbon Standard (VCS) and Gold Standard-VER are feasible, requiring administrative costs for re-registration and/or project conversion processes. As of October 2016, one cook stove project in India had completed the formal process of deregistration from the CDM to become a Gold Standard VER project
- ***Sectoral based crediting mechanisms*** may be feasible only as a pilot option, since such mechanisms do not yet exist on any significant scale, and are unlikely to before 2020.

Potential of the measures for cost-effective removal of the barriers

Any of the international market based measures identified could remove the barriers to increase the likelihood of project cook stove continuation. ***Credit purchase facilities*** and ***alternative crediting mechanisms*** could activate continuation scenario C1 by restoring the active participation of project owners who would replace faulty equipment and monitor its usage. However, the price of the credit purchase must be sufficient in order to reactivate project owners: some existing credit purchase facilities have signed agreements with cook stove projects, such as the World Bank Ci-Dev initiative and the Future of the Carbon Market Foundation, but others have prioritised cost effectiveness, focusing on projects such as landfill gas, methane avoidance and N_2O (Sharma, 2015; World Bank, 2015c); the average price of purchases from the major facilities is somewhat lower than that usually required by cook stove project operators (Global Alliance for Clean Cookstoves, 2013a). A pilot ***sectoral based crediting mechanism*** could implement domestic policies to mitigate the barriers for continuation scenario C2, in which the household replaces the efficient cook stoves by their own means.

These two different streams of support provision may have different potential impacts in the short and long term. Approaches that aim for continuation through scenario C2, where the household is incentivised to replace the equipment by their own means, may take a while to establish due to the depth of challenges associated with the key barriers, but could have a greater long term impact, and may also be cost effective in the long term if reliance on third parties and finance can be reduced in part or full.

Reactivating project owners through credit demand is likely to lead to the continuation of mitigation in the short term. However, as the findings of this study suggest, several years of mitigation under project based crediting has not led to a transformational change in which the dependence of the activity on external support has diminished. Unless such support is provided over an extended period of time, and alongside other changes that would begin to mitigate barriers for the household, activities may remain dependent on credit based finance.

9.4.3 Domestic market and carbon pricing measures

The following domestic market based instruments could be enacted, in place of or in addition to non-market based policy instruments:

- ***Domestic emissions trading system (ETS):*** There are currently no emission trading schemes in either India or Kenya which makes their introduction and implementation before 2020 unlikely. More importantly, such a policy instrument is most suitable for large emitters and would be impractical for emission reduction activities at the household, and poses considerable challenges in distinguishing renewable from non-renewable biomass.
- ***GHG taxation:*** Taxation schemes are normally targeted at upstream energy industries or major emitters, which would not have an impact on usage of wood based fuels in rural communities. Implementing a tax on emissions downstream entities directly, including households, would be especially challenging in any country and is entirely unfeasible in poorer rural communities of Kenya and India. Carbon taxes on non-renewable biomass use would also pose considerable challenges in distinguishing renewable from non-renewable biomass sources.
- The potential use of CERs for ***domestic offsetting*** of mandatory targets in India and Kenya is currently limited, due to the lack of mandatory emission caps for entities in these countries.

9.4.4 International support for domestic measures

Potential domestic policies and measures are identified and briefly discussed based on the insights from this study. A full analysis of promising measures is beyond the scope of the study but should be conducted for the detailed design of international support options. An initial overview of potential measures shows that a reasonable number of initiatives to provide support for project continuation are already under way:

- Measures related to capacity building:
  - ***Awareness campaigns:*** The health risks associated with the burning of solid fuels are often not known by many consumers and their awareness of the benefits associated with alternatives is limited. The World Bank (2015) argues that this market failure cannot be addressed without government and donor support to help finance schemes to educate consumers (i.e. via educational campaigns and training workshops) on the advantages of correctly using clean and improved cook stoves. For example, in India, the Jal Nirmal Project (funded 85 % by the World Bank) focuses on raising awareness to increase the likelihood that householders will permanently adopt improved cook stoves (Global Alliance for Clean Cookstoves, 2013b).
  - ***Technical support:*** The provision of technical training (i.e. to install, repair cook stoves / business development support) is essential for building the capacity of local communities to support the continued use of improved and clean cook stoves over the long term. One of the strengths of the National Program for Improved Cookstoves (NPIC) in India was the identification of demand for support from local level bureaucracies and the transfer of technologies through training sessions (Global Alliance for Clean Cookstoves, 2013b). A key objective of the Paris-Nairobi Climate initiative is to promote a value chain approach to the provision of energy services in Kenya by building human and institutional capacity (Paris-Nairobi Initiative, 2011).
- Policies related to energy climate policies:
  - ***Targeted subsidies:*** According to the World Bank (2015), the number and quality of national cook stove programs have risen sharply since the 1970s. The type of cook stove programs has evolved from initial large-scale subsidies to more demand driven models that incorporate both indirect support for market development and direct support for stove producers and customers. However, the quality of previous national programs has been variable with the majority of cook stoves installed under the NPIC in India no longer in use (World Bank, 2015d).

Based upon an assessment of subsidies in Kenya, Lambe et al. conclude that subsidies may in general be more effective if targeted upstream in the value chain (i.e. R&D, manufacture, distribution) with targeted end user subsidies only for very low-income households.

- ***Setting standards:*** The World Bank (2015d) argues that more progress is required with regards to the setting of standards. Given the limited capacity of local testing laboratories, investment in global testing centres is required along with better access to their facilities for cook stove manufacturers. More work is also necessary to finalise the ongoing international standardisation process (i.e. agreeing upon ISO standards and establishing an ISO Technical Committee and importantly the harmonisation of global ICS standards with local country standards). Based upon information from the Global Alliance for Cookstoves, cook stove standards are currently in place in India (i.e. BIS 13152, Portable Solid Bio) and in Kenya (i.e. KS 1814-1)(Global Alliance for Clean Cookstoves, 2016b).
- ***Tax exemptions:*** Taxes and duties not only exclude the best cook stove technologies from domestic markets, but may also affect the potential for domestic assembly of imported components due to higher costs (World Bank, 2015d). Following the 2016 annual budget in Kenya, the 16 % value added tax on liquefied petroleum gas (LPG) was removed only three years after its introduction (Global Alliance for Clean Cookstoves, 2016a). In addition, import duties on cook stoves and fuels were reduced from 25 % to 10 %. Tax exemptions such as these are designed to support the cook stove value chain and ultimately reduce costs for the end user.

- ***Innovative financial models:*** In order to ensure that the affordability barrier is overcome, private sector stakeholders have developed innovative financial models (i.e. layaway plans, 'pay as you go' pricing, fuel/stove rental models, electronic payment metering) that can minimise or even remove the upfront cost associated with purchasing a clean cook stove (World Bank, 2015d). These models should be further promoted by national governments (i.e. in awareness campaigns) to increase the uptake of clean cook stoves.

These potential non-market based domestic support measures could be supported at the international level through ***NAMAs, results based financing (RBF)***, or ***direct financial support or technical assistance*** for the development and implementation of domestic measures. As discussed in section 9.3.4, the development of NAMAs for implementation before 2020 is unlikely in India as the country has demonstrated little motivation for engagement in NAMA development. Kenya, on the other hand, has shown interest in the development of NAMAs with existing NAMA proposals and concepts in the energy and waste sectors (NAMA Database, 2015; UNFCCC, 2016b), and has recently launched a new NAMA development process for household energy efficiency, to include lighting and cook stoves (UNFCCC, 2016a). The NAMA, which is developed under the UNDP Low Emissions Capacity Building programme, plans to distribute 1 million cook stoves through the private sector, by producing incentives for the establishment of infrastructure and support services for manufacturing and distribution. The NAMA will also include capacity building and training programmes, and will be implemented by the National Electricity and Renewable Energy Authority. The NAMA currently seeks finance from international grants and loans to complement domestic resources (UNFCCC, 2016a).

9.4.5 Summary of support options for cook stove projects in India and Kenya

Support options for cook stove projects depend upon the mode of project continuation envisaged. Support can either aim to re-incentivise the participation of the third-party project owner and operator, or it can remove the barriers for the continuation of the mitigation activity on the initiative of the individual households. For pre-2020 impact with long term potential, a mixture of both approaches might be appropriate.

The support options are similar for Kenya and India. Table 53 shows that there is potential from international market based measures, mostly through potential to re-engage the project owners and operators, although domestic market based measures are considered mostly unfeasible at the present.

There is also significant potential for domestic non-market measures through various technical and financial support modes, which may remove several barriers for the continuation of the project on the initiative of households.

Some of these potential support options are currently being used in areas of Kenya and India. Several projects have been selling a significant volume of credits to the voluntary offset market for preferential prices in recent years, whilst programmes supported by international organisations are underway for the development of innovative financial models and for training and awareness. A NAMA is under development in Kenya to combine many of these measures into a wider reaching programme. However, existing programmes reach only a small number of households and efforts should be further supported, up-scaled and replicated to increase coverage and impact.

Table 53: Summary of potential policy options for cook stove projects in India and Kenya

Policy / measure	Policy assessment		Barrier directly addressed
	Practical feasibility	Barrier removal effectiveness	
Market and carbon pricing based measures			
International			
Credit purchase facilities	✓	✓	Engagement of the project owner
CER demand for vol. offsets	✓	✓	Engagement of the project owner
Alt. crediting programmes	✓	✓	Engagement of the project owner
Pilot sector-level crediting	•	✓	Potentially all barriers
Domestic			
Emissions trading scheme	×	n.a.	-
GHG / fossil fuel taxation	×	n.a.	-
Domestic offsetting	×	n.a.	-
Domestic non-market measures (e.g. with international support through NAMAs, RBF or direct support)			
Capacity building	✓	✓	Awareness and cultural preferences
Standards	✓	•	May lead to reduced cost of stoves
Subsidies / tax exemptions	✓	•	Cost of stoves
Innovative financial models	✓	✓	Cost of stoves

Source: Authors' own elaboration based on findings from the study
Green and red refer to positive and negative conditions, respectively. Yellow is used where the conditions are highly uncertain, highly variable according to specific circumstances or where the measure may be effective only when used with complementary measures. Where one element is found to have negative conditions, the following aspects are not considered (noted n.a.).

9.5 Summary of Findings for Policy Options

This section has provided a summarised insight into the potential suitability of various market and non-market based support options for commercial livestock manure management in Mexico and Brazil, biomass captive energy and IPPs in India, and efficient cook stoves in India and Kenya.

The findings of the section are summarised in Table 54.

Table 54: Summary of suitability of international support options for vulnerable project types

	International market based mechanisms		Domestic market based mechanisms	International support for domestic measures
	Project based crediting	*Pilot* sector-level crediting		
Commercial livestock manure management (Mexico & Brazil)	Low suitability	Potential suitability (long term)	Low suitability	High suitability (long term)
Biomass IPPs (India)	Potential suitability (short term)	Low suitability	Potential suitability	High suitability (long term)
Biomass captive energy (India)	Suitable only in combination with domestic measures	Low suitability	Potential suitability	High suitability (long term)
Cook stoves (Kenya and India)	High suitability (short term)	Potential suitability (long term)	Low suitability	High suitability (long term)

Source: Authors' elaboration based on the findings of this report

International market based mechanisms (project based crediting)

Options to support the continuation of project based crediting for the international market, for example through credit purchase facilities or voluntary offsetting, may have a role for all project types except for commercial livestock manure management in Mexico and Brazil, where it is considered highly unlikely that the third-party project operators could be reactivated, and where project crediting periods are at the point of expiration in most cases. This finding is very specific for the countries analysed due to the prevailing conditions, and the finding is not necessarily transferable to other countries where conditions for credit issuance may be significantly better. It is notable that while enhanced CER demand could contribute significantly to barrier removal for project continuation for cook stoves, biomass IPPs and biomass captive energy, these project types seem not to have been prioritised by most of the major credit purchase facilities. Neither the World Bank Pilot Auction Facility, the NEFCO Norwegian Carbon Procurement Facility, nor the purchase facility of the Swedish Energy Agency have purchased credits from these project types, although they do not all explicitly exclude the project types from their theoretical target scope. The World Bank Ci-Dev initiative and the Future of the Carbon Markets Foundation have signed agreements with cook stove projects.

Although there may a significant role for supporting projects through international mechanisms with project based crediting for these project types, such as credit purchase facilities for CERS, the findings of the study indicate that such measures would be best taken alongside other international support for domestic measures. In particular, for commercial livestock manure management in Mexico and Brazil and cook stoves in Kenya and India, where owners and operators of the CDM projects are usually third party to the emission source activities, the evidence indicates that support through market finance alone may have limited prospects for long term transformation, as projects have remained dependant on these finance sources. Since these projects are vulnerable now after the effective withdrawal of several years of CDM support, there is little reason to believe that they might operate more independently after several more years of market based support. One could argue that this makes these kinds of activities fundamentally unsuitable to market finance. On the other hand, market finance could be seen to have a major role for short term pre-2020 action, whilst other international support targets the barriers and enabling environment for long-term transformation.

The transformation impact of this support measure is also restricted in that it only directly impacts registered CDM projects and may have limited impact on the broader sector, including many activities or potential activities that are not registered under the CDM. The original development of these projects would have had positive spill over effects for the sector through the import and application of new technologies and the experiences gained; this wider impact of support is still partially relevant for the continuation of existing projects, although not to the same extent.

International market based mechanisms (Sector based crediting (pilot))

Sectoral crediting mechanism approaches are being piloted, in various forms, by a handful or organisations worldwide. Pilot approaches might be suitable for commercial livestock manure management in Mexico and Brazil and cook stoves in India and Kenya, although for cook stoves the feasibility is uncertain due to the potential complications for determining baselines and monitoring performance of all households. For both of these activities, sectoral crediting approaches, if well designed, have the potential to overcome major barriers through a mixture of domestic measures that provide incentives and improve the enabling environment. This could lead to long-term impact and, importantly, may positively impact not only existing CDM projects but hundreds of similar activities in the countries which were not registered in the CDM. For biomass projects in India, sector-level crediting mechanisms may be practically feasible in general in the long-term, but the scale and complicated conditions of the sector do not make it conducive as a testing ground for pilot approaches.

The potential for mitigation impact to occur at CDM projects in the immediate short term before 2020 may be somewhat limited through pilot sectoral mechanisms. Pilot mechanisms are likely to take at least 2-3 years to design before being implementation ready. Thereafter, many of the measures implemented are likely to be aimed at mid- to long-term impact, although short term incentives can also be put in place to deliver mitigation results in the first years of implementation.

Other international support for domestic measures

The findings of the study indicate a significant role for long term impact in all of the identified vulnerable project types through international non-market based support for the implementation of domestic measures. Many of the barriers facing project continuation relate to conditions that are not directly related to financial attractiveness of the mitigation activity, such as needs for capacity building and awareness, or for the formalisation and development of market supply chains. For these barriers, as well as those which are related to finance, such as availability of capital, domestic measures can adjust the enabling conditions leading to the long-term removal of these barriers, rather than just their temporary circumvention.

For cook stove projects, a number of international support programmes, including NAMAs and programmes led by multilateral institutions and development banks, are already under development and implementation to support such measures. The coverage of such programmes should be up-scaled through the development of new financial models for leveraging private sector capital, and the identification of new channels of international climate and development finance. Volumes of public and private finance as well as diversity of channels have increased significantly in recent years (Buchner, Trabacchi Chiara, Federico, Abramskiehn, & Wang, 2015), whilst this increase is set to continue in the years up to 2020, as more finance is mobilised for the Green Climate Fund (GCF) and multilateral development banks look increasingly to expand on their portfolio of climate related projects. Results based financing models, based on MRV-able outcomes, including even sectoral crediting approaches, may also be a feasible and attractive option for cost effectively channelling climate finance, especially for the removal of barriers for which upfront capital is less of an issue.

10 Conclusions

The CDM has registered nearly 8,000 projects which have the potential to issue up to 7.6 billion CERs in the period 2013-2020 (UNEP DTU, 2016). After the collapse of CER prices, a key policy question is which of these projects are likely to continue GHG abatement in the absence of CER revenues, and which are vulnerable of discontinuing GHG abatement. Ensuring continued GHG abatement of existing CDM projects could be a cost-efficient way of contributing to pre-2020 mitigation ambition. Continued abatement could be incentivised through both national and international support and both carbon-market based measures and other policies or measures.

Building on earlier research (Schneider & Cames, 2014; Warnecke, Day, & Klein, 2015; Warnecke, Day, & Tewari, 2015), this study aims to contribute to an understanding which projects are vulnerable of discontinuing GHG abatement and what policies and measures may be best suited to ensure continued GHG abatement. Towards this end, this report has developed a methodology for the assessment of CDM project vulnerability for discontinuation of the mitigation activity and applied it to selected project types and countries in three CDM sectors: methane avoidance, biomass energy and household energy efficiency.

Summary of results for assessed project types

Table 55 presents an overview of the results for the projects types assessed in detail for this research.

Methane avoidance projects

- ***Commercial livestock manure management projects*** are generally at a low risk of discontinuation in Thailand since the ability to sell electricity from biogas to the grid makes continuation highly lucrative and the capacity of farm owners to continue to operate the equipment is usually sufficient. In contrast, farms in Mexico and Brazil often have insufficient capacity to continue to operate the mitigation equipment, which was originally operated by third party participants; many of these farms are known to have already ceased mitigation. The lack of ability to sell to the grid in Mexico and Brazil also reduces the incentive to overcome this barrier. The mitigation impact of project continuation approximately 2 M t CO_2e per year in both Mexico and Brazil. Due to the permanent closure of third party CDM project owner businesses that were operating the mitigation equipment, as well as the near-expired crediting periods of most projects, restored CER demand through international or domestic markets is not an effective means to support continuation of these projects. Domestic policy measures have the greatest potential to remove the barriers for project continuation – such measures could be driven by various international support channels, including a pilot sector-level crediting mechanism.
- ***Waste water*** projects in India, Malaysia and Thailand are at low risk in the countries analysed due to the significant benefits from energy production. These activities are now very common even outside of CDM projects.
- The risk of project discontinuation for ***composting*** projects in Malaysia is identified as uncertain, due to the variability of conditions. Although some projects are likely to continue, there is considerably uncertainty due to changeable local market conditions and the immaturity of the compost market, and some projects are understood to be in the process of dismantling. However, the direct mitigation impact from the continuation of these activities may not be significant, since palm oil solid wastes might be used for other activities if the CDM projects discontinue. These other uses would also avoid the GHG emissions from decay of the solid wastes. The emission reductions may thus continue, even if the CDM projects discontinue.

Table 55: Summary of results for assessed project types

		Risk of mitigation discontinuation (red = high; green = low; yellow = uncertain; grey= not assessed)							Suitability of support options			
									Intl. market-based		Domestic market-based	Intl. support for domestic measures
		Brazil	India	Kenya	Malaysia	Mexico	Pakistan	Thailand	Project-level crediting	Sector-level crediting (pilot)		
Methane avoidance	Commercial livestock manure management	red	grey	grey	grey	red	grey	green	Low	Possible / uncertain	Low	High
	Waste water	grey	green	grey	green	grey	grey	green	Support options not assessed. Project at low risk.			
	Palm oil solid waste compos-ting	grey	grey	grey	grey	grey	grey	grey	Not assessed. Uncertain risk and mitigation impact.			
Biomass energy	Bagasse power	green	green	grey	grey	grey	grey	grey	Support options not assessed. Project at low risk.			
	Independent power producers (IPPs)	grey	red	grey	grey	grey	grey	green	Possible/ uncertain	Low	Possible/ uncertain	High
	Captive biomass energy	grey	red	grey	grey	grey	grey	grey	Combined with domestic P+M	Low	Possible/ uncertain	High
Household EE	Lighting	grey	green	grey	grey	green	green	grey	Support options not assessed. Project at low risk.			
	Cook stoves	grey	red	red	grey	grey	grey	grey	High	Possible/ uncertain	Low	High

Suitability of options is marked possible/uncertain where the feasibility of the measure is not considered low, but uncertainty on feasibility or effectiveness remains due, for example, to the uncertain or untested nature of the support option, or where the suitability is highly variable based on individual project conditions.

Biomass energy projects

- ***Bagasse power*** projects in the sugar industry are at low risk of discontinuation in both India and Brazil. These projects are integrated in the sugar industry and utilise bagasse directly from the industries' own residues. The practice of using bagasse for captive cogeneration in the sugar industry is common, and the extension of bagasse utilisation for grid electricity export has highly positive economic conditions.
- ***Biomass energy*** projects (including captive energy projects and IPPs) are generally at high risk of discontinuation in India, where biomass prices are relatively high and the biomass supply chain is unreliable. The risk of projects in Thailand is comparatively lower, due to more favourable conditions for the price and availability of biomass for projects. The mitigation impact of the continuation of vulnerable biomass projects in India is uncertain; the direct emissions impact depends on the extent to which the biomass would be used for other purposes if the CDM projects discontinue and the biomass supply increases as a result of a policy program supporting existing projects. Domestic policy programmes that address the unreliability of the supply chain for biomass are likely to have the greatest impact on barrier removal for continuation. Restored CER demand may support some projects by increasing the financial attractiveness of biomass use, especially when used in combination with other measures to address the reliability of the market supply.

Household energy efficiency projects

- ***Energy efficient lighting*** projects for households are considered to be at low risk of discontinuation in Mexico, India and Pakistan. In Mexico, regulations require the continuation of the project. In India and Pakistan, households are likely to finance replacement of bulbs due to their increasing market presence, the decreasing costs and improving knowledge on their benefits.
- ***Energy efficient cook stove*** projects for households are considered to have a high risk of discontinuation in India and Kenya, once the existing stoves cease operation. Regulations do not require the use of efficient stoves in both countries. Third-party project owners have no incentive to continue financing the replacement of stoves and households are unlikely to finance this due to the considerable costs and other barriers including knowledge of benefits and cultural preferences. The emission reduction impact of project continuation for cook stove projects in India and Kenya could be up to 0.53 M t CO_2e and 0.72 M t CO_2e per year, respectively, although some studies indicate that CDM methodologies may over-estimate potential emissions reductions in real-world usage (Aung et al., 2016; Bailis et al., 2015). Programs supporting the continued use of clean cook stoves should therefore carefully consider how emission reductions are quantified. Restored CER demand may be an effective means of supporting project continuation due to the provision of an incentive for the re-engagement of the third party project owner, who may re-assume responsibility for monitoring use of stoves and administering repairs and replacements where necessary.

General characteristics of project vulnerability

In addition to the findings for project vulnerability from the project types assessed in detail, this study also uncovered broader insights for other project types. These insights could be explored in greater detail in subsequent research in order to obtain a clearer picture on the status and prospects for mitigation activity under the CDM as a whole up to 2020.

Projects for renewable energy generation from hydro, wind and solar power technologies, which account for approximately half of the CDM's emission reduction potential between 2013 and 2020[41], may have entailed large capital costs for implementations, but are generally at low risk of discontinuation once implemented due to the receipt of revenues from electricity sales and relatively limited operating expenditures. The assessment of project discontinuation vulnerability considers only the situation of projects at the current point in time. Whether the economic conditions favour continuation of the activity or not in the absence of CERs at the present time is not in any way a reflection or even an indication of the additionality of projects at the point of their inception. Furthermore, it needs to be considered that the additionality demonstration does not only contain financial analyses but also takes into account other barriers preventing the project implementation like investment or technological constraints. Conditions for biomass energy are not as positive as for other renewable energies, as discussed in the previous section. Projects for energy efficiency, which account for nearly 10 % of the CDM's emission reduction potential up to 2020, are usually also at low risk of discontinuation once implemented, due to significant ongoing cost savings and very limited or no continued additional operating expenditures.

41 According to ex-ante project estimations from PDDs (UNEP DTU, 2016)

In some cases, these projects can physically not be reverted. Conditions for household cook stove projects are likely to deviate from these trends, as analysed in this study and summarised in the previous section.

In contrast, project types which do not accrue significant ongoing financial benefits aside from CER revenues are often generally at higher risk of discontinuation. For these project types, continued mitigation is typically only ensured as long as financial support, either through subsidies or carbon market instruments, is provided or unless regulations require mitigation. The study shows for example that efficient cook stoves may face the risk of discontinuation in case that households are unlikely to finance their replacement themselves. All the experiences mentioned in the study might be relevant when considering the most effective means of long-term support for mitigation at new project sites or emission sources, pre- or post-2020.

Another key insight from this study is that ownership structures for project implementation matter a great deal to the long-term sustainability of action. Projects which involve multiple parties – i.e. the site or property owner, the investor and the operator of the mitigation activity are not all the same entity, or associated with that entity – are more likely to be vulnerable to discontinuation, regardless of the general economic attractiveness of the activity. The division of financial benefits between project parties may be such that the parties operating the activity have no incentive or not the necessary capacity to remain engaged with the project without CER revenues (e.g. household cook stoves, household lighting, or commercial livestock manure management in some countries). The experience with these projects under the CDM might provide valuable lessons for future approaches for new projects: project approaches relying on significant third party participation – which includes a large proportion of new PoA projects, and could be a common characteristic of some approaches for sectoral crediting mechanisms (in particular up-scaled project based crediting) – should pay close attention to capacity building and transfer of knowledge to optimise the prospects for long-term impact after the withdrawal of the third parties due to crediting period expiry or unforeseen circumstances.

Supporting continuation of vulnerable projects for pre-2020 mitigation

For the specific project types found to have a high vulnerability for the discontinuation of emission reductions, this study analysed options for supporting project continuation pre-2020, and estimated the potential emission reductions.

A key insight from the analysis is that the continuation of vulnerable projects may not always result in emission reductions. For some project types, economy-wide GHG emissions could be the same, whether or not the project continues the mitigation activity, since the emission reductions would continue at other sites. For example, the mitigation outcome for the continuation of two project types analysed in this study – palm oil solid waste composting in Malaysia and biomass energy in India – is highly uncertain, since competition for biomass resources and solid wastes may mean that the biomass or waste may be used elsewhere if the CDM project activity discontinues. Assessing the local conditions and causal relationships with other activities is thus important to determine whether continuation of the activity at the project site will result in further emission reductions at the economy level. This insight does not contest the assessment of additionality at project inception, but recognises that changes in circumstances since project inception may mean that further emission reductions cannot always be expected from the continuation of vulnerable projects today.

The continuation of vulnerable projects could be supported in different ways. This study assessed both domestic and international carbon market instruments as well as the implementation of domestic policies with or without international support.

Several initiatives have recently been launched with the aim to support continuation of vulnerable projects through the provision of new sources of demand for CERs. Such sources may include, for example, multilateral or bilateral credit purchase facilities, such as the pilot auction facility operated by the World Bank, or offsetting programmes under domestic mechanisms, such as the use of CERs in the ETS in South Korea or to meet tax obligations in Mexico and South Korea. The restoration of CER demand was found to have a potential positive influence on project continuation on some, but not all projects. Firstly, not all vulnerable project types face the same barriers as they did at the conception of their project; and hence restored CER finance may not remove the barriers for all vulnerable project types. Secondly, even in the cases that restored CER demand is able to support project continuation, this is sometimes found to have only a short term impact; CER revenues may help to temporarily circumnavigate some barriers, but will not always lead to those barriers being removed in the long-term, after carbon finance is eventually withdrawn.

Whilst the provision of support for continuation through restored CER demand is found to have variable suitability for different project types, support through domestic policies and incentive programmes, initiated unilaterally or through international support, was found to have high potential for removing the various financial and non-financial continuation barriers of all the project types assessed. There is significant potential in many sectors for policy programmes to be initiated unilaterally based on existing regional best practices (Healy et al., 2016). Proposals for supported Nationally Appropriate Mitigation Actions (NAMAs) may be an effective channel for attracting support where international finance and/or technical expertise is required. For some project types, sector-level crediting mechanisms may also offer an appropriate channel for supporting a policy and programme oriented approach driven at the sector level, although the limited development of these concepts mean that only a pilot based approach would likely be feasible before 2020.

Implications for design of future post-2020 mechanisms

Article 6 of the Paris Agreement introduces cooperative approaches based on internationally transferred mitigation outcomes (ITMOs) (Art 6.2), a mitigation and sustainable development mechanism (Art 6.4), and non-market approaches (Art 6.8). Article 6.1 frames these mechanisms explicitly ambition raising mechanisms, which may constitute a significant difference to the flexibility mechanisms of the Kyoto Protocol. The fundamental design features of these mechanisms are not yet determined. The various experiences and lessons from the CDM are key to informing the design of these future mechanisms, to ensure that they effectively meet their objectives.

Achieving the goals of the Paris Agreement will require all countries to fully decarbonise their economies this century (mid-century for CO_2 emissions) (UNEP, 2016b). This marks an important change: the full decarbonisation of all sectors will require transformational change and avoidance of lock-in to carbon intensive technologies. Mechanisms intended to raise collective ambition to meet the PA goals should be clear about their specific objectives and whether support for certain project types is suitable based on these objectives; support channels and mechanisms will be needed to target emission reductions that can have a lasting long-term impact and the introduction of new zero- and negative-emission technologies, although mechanisms for short-term mitigation may also play an important role for currently stranded projects.

The findings of this research lead to the following insights with relevance for future mechanism design:

- The design of future mechanisms or purchase facilities should consider the risks that some project types could become stranded and discontinue mitigation in the case of a market collapse.
- For lasting impact of emission reduction outcomes, international support for mitigation options should seek the long-term removal of a range of financial and non-financial barriers.
- If project-level crediting is to continue under mechanisms of the Paris Agreement, safeguards should be considered to avoid the situation that vulnerable projects stop reducing emissions, once carbon finance ceases. For example, the Nitric Acid Climate Action Group initiative, launched by Germany in 2015, makes crediting support contingent on the introduction of supporting policies.
- Domestic policy-level approaches, driven at the national or sector level, might be best able to remove financial and non-financial barriers for mitigation action in the long-term. Such approaches seem to be key towards the end of triggering transformational change and ensuring integrated planning that avoids lock-in to carbon intensive technologies. Sector-level crediting mechanisms might be a potential channel to drive domestic policy-level approaches, but further road-testing of such mechanisms is needed to gain experiences for the further consideration of this option and its potential role.

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Annex I – Subtype categorisations

Methane avoidance

UNEP DTU categorisation

The UNEP DTU categorisation of methane avoidance includes projects that treat solid wastes, wastewater and manure to decrease the uncontrolled emissions of methane upon the decay of the wastes. This type does not include the avoidance of landfill gases related to the treatment of municipal solid waste, which are covered in a separate project type according to the UNEP DTU classification. In most cases, projects are based on controlled aerobic treatment or capture and destruction of methane through anaerobic treatment, flaring and/or utilisation. The methane avoidance categorisation includes a very broad range of projects with considerable variation in emission sources and abatement technologies.

Table 56 presents the methane avoidance project type, drawing upon the UNEP DTU classifications, as well as the major methodologies. The number of projects reported in the table equate to total number of projects from the eight countries selected. Adjustments to the UNEP DTU categorisation were made in the following cases: project type, drawing upon the UNEP DTU classifications, as well as the major methodologies. The number of projects reported in the table equate to total number of projects from the eight countries selected. Adjustments to the UNEP DTU categorisation were made in the following cases:

- One project using the AMS-III.I. methodology (Methane recovery through controlled anaerobic digestion, with flaring or utilisation) belonged to a designated subtype *Aerobic treatment of wastewater*. This was the only project in this subtype. This project was moved to the subtype *Other wastewater* and classified along with other anaerobic to aerobic treatment projects already in this category. The *Aerobic treatment of wastewater* subtype was then closed.
- All but three of the projects from the subtype *Composting* were composting for palm oil solid waste. The other three projects were removed from the category, and the subtype was renamed *Palm oil solid waste composting*, for clarity.
- Five projects using the AMS-III.F. methodology (Avoidance of methane emissions through composting) belonged to the Palm oil waste subtype. These projects were moved to the *Palm oil solid waste composting* subtype.
- All remaining projects from the subtype Palm oil waste were for treatment of wastewater. The subtype was renamed *Palm oil wastewater*, for clarity.
- 59 projects assigned to the category *Wastewater* were for palm oil waste. These projects were similar to all other projects in the *Palm oil wastewater* category, and the separation of these projects into two different categories thus deemed inconsistent. The 59 projects in the category Wastewater were moved to the category *Palm oil wastewater*.
- One project using the methodology AMS-III.R. - Methane recovery and combustion for thermal energy in agricultural activities at household/small farm level – was moved to the subtype *Domestic manure*, from its initial UNEP DTU classification under *Manure*.

Table 56: Overview of the methane avoidance project type for the selected countries

Subtype and major methodologies	Number of projects
Manure	173
AMS-III.D.: Methane recovery and flaring or utilisation in animal manure management	129
ACM10/AM6/AM16: Manure management systems: Destruction of methane emissions and displacement of a more-GHG-intensive service.	42
AMS-I-C. / AMS-I-D. / AMS-I-F.: Methodologies for electricity generation (usually secondary to other methodologies)	43
AMS-III.F.: Avoidance of methane emissions through composting	4
AMS-I-E.: Switch from non-renewable biomass for thermal heat	1
AMS-III.AO: Methane recovery through controlled anaerobic digestion, with flaring or utilisation	1
Palm oil wastewater	82
AMS-III.H.: Anaerobic treatment system for methane recovery, and flaring or utilisation.	71
AMS-I-A. / AMS-I-C. / AMS-I-D. / AMS-I-F.: Methodologies for electricity generation (usually secondary to other methodologies)	40
Other wastewater	68
AMS-III.H.: Anaerobic treatment system for methane recovery, and flaring or utilisation.	39
ACM14/AM13/AM22: Treatment of wastewater through new anaerobic digester or dewatering.	16
AMS-I-A. / AMS-I-C. / AMS-I-D. / AMS-I-F.: Methodologies for electricity generation (usually secondary to other methodologies)	50
AMS-III.I.: Avoidance of methane production in wastewater treatment through replacement of anaerobic systems by aerobic systems	3
AMS-III.Y.: Methane avoidance through separation of solids from wastewater or manure treatment systems	2
AMS-III.AO.: Methane recovery through controlled anaerobic digestion, with flaring or utilisation	2
Palm oil solid waste composting	32
AMS-III.F.: Avoidance of methane emissions through composting	32
Domestic manure	18
AMS-I.E.: Switch from non-renewable biomass for thermal heat	17
AMS-III.R.: Methane recovery and combustion for thermal energy in agricultural activities at household/small farm level	6
AMS-I.C.: Methodology for electricity generation (usually secondary to other methodologies)	4

The number of methodologies is not necessarily equal to the total number of projects in all cases, since many projects use more than one methodology.

Analysis of homogeneity of subtypes and methodologies

Manure management

In Table 56 the largest subtype is *manure management*, in which the two major methodologies are very similar, but differentiated in their application to small or large scale projects. An analysis of projects with these two methodologies could be considered collectively, unless evidence arises to indicate that the conditions between small and large scale operations for manure management deviate significantly.

A further potential split of the manure management subtype, could be based on whether or not the project utilises recovered methane for energy generation, although it is not clear to which projects these conditions apply, since many projects use methodologies that allow for energy generation although they may not yet actually do so, whilst other projects may generate electricity alongside the project despite not having a secondary methodology to reflect this. The differences between these conditions is reflected in the analysis of the project type.

Other primary methodologies for manure management (AMS-III.F. and AMS-III.AO) are not considered further in our analysis due to the very low number of projects using these methodologies.

Palm oil and other wastewater

For palm *oil wastewater*, a single methodology accounts for all of the projects in this subtype, when excluding the electricity generation methodologies, for the same reason as stated for manure management.

For the other wastewater subtype, the make-up of the subtype according to the methodologies used is very similar as for manure management: two major methodologies are used frequently, and are very similar, but differentiated in their application to small or large scale projects. Like manure management, differentiation of projects according to whether or not they utilise recovered methane for energy generation may be relevant, but it is not possible to categorise projects in this way based on screening of methodologies or PDD details. This subtype includes wastewater from various industries, including but not limited to paper mills, distilleries, food processing plants, starch manufacturing plants, sewage, LPG processing plants, ethanol production and dairy products.

At this stage, it is not clear to what extent the conditions between palm oil wastewater and other wastewater projects may vary. An analysis of projects with these two methodologies is considered collectively, although potential deviations between the conditions of the two groups should be considered.

The remaining methodologies for wastewater (AMS-III.I., AMS-III.Y. and AMS-III.AO) are not considered further due to the very low number of projects using these methodologies. Some of these methodologies include more advanced technologies with increasing uptake in more developed countries, but the low project number indicates that the CDM has not set sufficient incentives for their regular uptake in developing countries, to date.

Palm oil solid waste composting

For palm oil solid waste composting, a single distinct methodology accounts for all of the projects within this type.

Domestic manure

Almost all projects within the domestic manure subtype use the same methodology - AMS-I.E. Switch from non-renewable biomass for thermal heat. These projects are different from projects in *the manure management* sub-type, as they refer to processes only at the domestic level, specifically the use of waste from domestic livestock for the generation of biogas for heat energy for domestic purposes. All of the projects in this category, including all methodologies, are likely to face similar conditions.

Selection of sub-types and countries for further analysis

Table 57 shows the identified project subtype groupings, along with the number of projects in each of the eight pooled countries. Domestic livestock manure management is not included for analysis in this study due to the resource limitations of the study, and the comparatively greater interest of the other project types, due to the larger number of projects and country coverage. The following categories were taken forward for analysis:

- Commercial livestock manure management projects in Mexico, Brazil and Thailand.
- Waste water projects in Malaysia, Thailand and India.
- Palm oil solid waste composting projects in Malaysia.

Table 57: Overview of the methane avoidance project type

Country	Commercial livestock manure management AMS-III.D. & ACM10/AM6/AM16	Wastewater (palm oil and other) AMS-III.H. & ACM14/AM13/AM22	Palm oil solid waste composting AMS-III.F.	Domestic livestock manure management AMS-I.E.
India	2	**11**	0	14
Thailand	**8**	**67**	0	0
Malaysia	0	**56**	**33**	0
Pakistan	0	0	0	1
Mexico	**99**	2	0	0
Brazil	**59**	1	0	0
Kenya	0	0	0	3

Biomass Energy

The UNEP DTU pipeline categorises biomass energy projects into 12 subtypes on the basis of the type of biomass. This subtype division based on the biomass type does not offer a categorisation which is particularly distinctive in terms of the mitigation activities undertaken, and as such does not provide a useful categorisation for assessment of their vulnerability. Upon detailed review of the biomass energy projects and insights of local experts, it was observed that several local conditions impact biomass energy projects. These include: security of fuel availability, which is linked to the biomass ownership and supply chains; technology modifications to suit biomass type; generated energy use; industry characteristics; domestic regulatory regimes etc. Therefore, it was decided to deviate from the UNEP-DTU classification and re-categorise biomass energy projects considering the type of industry, the type of biomass used, and whether the energy generated is used on-site or fed into the grid

Sugar production is the largest industry where biomass residues are used. We therefore create a separate category for this industry. The use of biomass residues in the cement industry and the palm oil industry may face different circumstances than most other project types where biomass is used to generate electricity and/or steam. We therefore introduce a separate category for use of biomass in the cement industry and the palm oil industry. We further identify that biomass briquettes and pellet production are a rather distinct form of biomass with potentially different production circumstances and introduce a category for this fuel type. All remaining biomass residue projects are categorized in two broad categories: one for cases where the electricity and/or steam is used on-site in an industrial facility and one for independent power production where all electricity is fed into the grid. This classification aims to distinguish the major project types occurring in the CDM, while taking into account potentially different circumstances among industries, plant configurations (captive / non-captive) and biomass types. Taking this approach, the following six categories emerged:

1. Bagasse energy in sugar industry

This category covers biomass energy projects developed in the sugar industry. All of them use their own biomass -. Bagasse i.e. the fibrous residue of sugarcane stalks generated after extraction of sugarcane juice in sugar manufacturing process. The projects can be cogeneration or heat generation only or power generation only; and with or without sale of power.

Projects using sugarcane bagasse in other industries for heat only/power only/cogeneration for captive use or independent power production are covered in category 4 and 5 respectively.

2. Biomass energy from palm oil solid wastes in the palm oil industry

This category covers biomass energy projects developed in the palm oil industry, using palm oil solid wastes from palm oil production. The projects can be cogeneration or heat generation only or power generation only; and with or without sale of power.

3. Biomass use in cement production

This category includes projects that use biomass residues to partially replace fossil fuels for clinker production in cement kilns. Most projects use methodologies ACM3 and AMS-III.AS. Other types of mitigation activities in the cement industry, such as energy efficiency improvements by technology upgrades, waste heat recovery and clinker replacement by use of blending materials, are outside the scope of this sub-type.

4. Biomass energy using briquettes and pellets

This category includes projects that use biomass briquettes and/or pellets for generation of steam for use in an industrial facility. Projects that involve production of pellets/briquettes and claim credits for methane avoidance are beyond the scope of 'biomass energy' and not covered in this sub-type.

5. Other biomass energy projects with captive energy use

This category includes all other biomass energy projects which generate and use electricity and/or steam and use the electricity and/or steam on-site at an industrial facility. Both heat generation only, power generation only and cogeneration projects are covered. The biomass types covered include agricultural residues (e.g. rice husk, mustard stalks, poultry litter, etc.), forestry biomass, forestry residues (e.g. generated in the process of fuelwood and charcoal production), industrial bio-residues (e.g. palm oil 'solid' wastes, saw mill wastes, bagasse etc.), other biomass residues (municipal solid waste, animal wastes etc.). Biomass/biomass residues can be the project developer's own or procured from elsewhere. The energy generation could occur in a boiler or through gasification of the biomass and subsequent combustion.

It must be noted that bioenergy projects developed in the sugar and cement industries are excluded here. These are covered under category 1 and 2 respectively. Similarly, projects involving pellets/briquettes are covered under category 3.

6. Independent electricity production from biomass

This category includes independent power projects that export electricity to the grid or sell it to a third-party, thus replacing need for fossil fuel based generation in the grid or at the third party. An independent power producer is a private entity that owns and operates facilities for the generation of electricity. An IPP can be standalone, i.e. it is a standalone power generation company with electricity sale the only business of the project owner, or associated to an industrial facility as a subsidiary, Joint Venture, associated company etc. The biomass types as well as the generation technologies covered are the same as in the previous category. Biomass/biomass residues are procured from elsewhere.

Table 58 summarises the coverage of each category:

Table 58: Overview of the categorisation for biomass projects

Category	Industry	Process		Biomass type	Biomass ownership			Energy use		
		Cogeneration/ heat only/ power only	Calcination		Own	Procured	Own + Procured	Captive use only	Power export only	Captive use and power export
1. Biomass energy in sugar industry	Sugar	All possible		Bagasse	✓			✓	✓	✓
2. Biomass energy in palm oil industry	Palm oil			Palm industry residues	✓			✓	✓	✓
3. Biomass energy in cement production	Cement		✓	Any biomass falling under CDM definitions		✓				
4. Biomass energy using briquettes and pellets	Any industry except those covered in categories 1,2 and 3	All possible		Pellets/ Briquettes	✓	✓	✓	✓	✓	✓
5. Other biomass energy projects with captive energy use	Any industry and biomass except those covered in categories 1,2 and 3	All possible		Any biomass falling under CDM definitions			✓	✓		
6. Independent power production using biomass	RE power production using any biomass except in category 3	Power only/ Cogeneration		Any biomass falling under CDM definitions			✓			

Selection of sub-types and countries for further analysis

These groupings are presented in Table 59 along with the number of projects in each of the eight countries.

Table 59: Overview of the biomass energy project type

Country	Bagasse energy in sugar industry	Biomass energy in palm oil industry	Biomass energy in cement production	Biomass energy using briquettes or pellets	Other biomass energy projects with generation and captive use	Independent power production using biomass
India	**44**	1	4	11	**114**	**114**
Thailand	4	1	0	0	0	**22**
Malaysia	0	13	1	1	**14**	7
Pakistan	1	0	3	0	1	0
Mexico	2	0	9	0	0	0
Brazil	**27**	0	0	0	10	7
South Africa	1	0	0	1	2	2
Kenya	1	0	0	1	0	0

Three distinct project groups appear most interesting for analysis based on having the greatest number of projects in the biomass energy project type. These are:

1. Bagasse cogeneration in sugar industry (including methodologies ACM6/AM15, AMS-I.C. & AMS-I.D.), with a focus on Brazil and India.
2. Biomass/Biomass residues used for power export, with a focus on Thailand and India.
3. Biomass/Biomass residues used for captive energy generation and use, with a focus on India.

Household energy efficiency

UNEP DTU categorisation

The UNEP DTU categorisation of *household energy efficiency* relates to three main sub-categories including energy-efficient appliances (such as refrigerators), lighting (such as the introduction of compact fluorescent lamps (CFLs)) and energy-efficient cook stoves.[42] Generally, there is not much variation of project types with these sub-categories.

Table 60 shows an overview of these main subtypes within *household energy efficiency* project types according to the UNEP DTU classifications, as well as the major methodologies. The number of projects reported in the table equate to the total number of projects from the eight countries selected.

42 Actually, the category includes four additional sub-categories, namely a) biogas from municipal solid waste, b) lighting & insulation & solar, c) solar lamps and d) water purification. However, there are no projects in the eight selected countries, which fall into sub-categories a, c & d, while only one project in South Africa falls into sub-category b. Since the latter sub-category is both, complex from a methodological perspective and rarely applied, we excluded this sub-category from further analysis.

Table 60: Overview of household energy efficiency project types

Subtype and major methodologies	Number of projects[40]
Appliances	12
AM70	2
AMS-II.G.+AMS-III.AV.+AMS-I.A.	8
AMS-II.M.	1
AMS-III.AV.	1
Lighting	163
AMS-I.A.+AMS-II.J.	1
AMS-II.C.	30
AMS-II.J.	132
Stoves	51
AMS-I.E.	10
AMS-II.G.	41

Table 60 demonstrates that almost all household energy efficiency projects are small-scale projects. Furthermore, there is a clear differentiation between categories of projects in terms of the number.

Analysis of homogeneity of subtypes and methodologies

The largest subtype is lighting accounting for the bulk of projects (163) and for 62 %[44] of expected emission reductions in the category household energy efficiency. The two main methodologies refer to new energy-efficient equipment in general (AMS-II.C.) and more specifically to energy-efficient light bulbs (AMS-II.J.). The methodologies are similar in a way that both consider the reduction of electricity consumption and corresponding GHG emissions as the main outcome of the projects. An analysis of projects with these two methodologies could be considered collectively, unless evidence arises to indicate that the conditions for lighting projects deviate significantly. Due to the small number of projects (one project only), the combination of methodologies AMS-I.A and AMS-II.J is not specifically considered.

The second-largest subtype is stoves accounting for 51 projects and for 21 % of expected CERs in the category household energy efficiency. The two methodologies refer to switch from non-renewable biomass for thermal applications by the user (AMS-I.E.) and to energy efficiency measures in thermal applications of non-renewable biomass (AMS-II.G.). The methodologies are similar in a way that both consider the reduction of the use of non-renewable biomass and corresponding GHG emissions as the main outcome of the projects. However, there are also some differences, as under AMS-II.G more efficient stoves are used, while under AMS-I.E usually stoves are replaced, e.g. by solar cookers. Solar cookers, which are likely to be used in parallel to another cooker, may have different conditions for continued use than replaced stoves. We nevertheless look in to both methodologies because the comparison may allow to better identifying what exactly triggers continued use of the devices and what exactly constitutes a barrier for continue use.

The remaining subtype is appliances accounting for 12 projects and for 16 % of expected CERs in the category household energy efficiency. It is recommended not to consider the two methodologies AMS-II.M. and AMS-III.AV since these relate to two projects only. The two other project types use a combination of methodologies for "water purification" (AMS-II.G. + AMS.III.AV. + AMS-I.A., 8 CPA of 1 PoA) or one large-scale methodology for "energy-efficient refrigerators" (AM70, 2 projects). In other words, there are significant differences in the methodological approach between both project types and both types represent a limited share in terms of number of projects and in terms of potential CER supply.

43 Including Component Project Activities (CPA).
44 Not displayed in the table.

Selection of sub-types and countries for further analysis

Table 61 provides an overview of how the project types are allocated among the selected countries.

Table 61: Overview of the household energy efficiency project type

Country	Lighting AMS-II.C. AMS-II.J.	Stoves AMS-I.E. AMS-II.G.	Appliances AM70 AMS-II.G.+AMS-III. AV.+AMS-I.A.
India	**80**	**31**	10
Thailand	0	0	0
Malaysia	0	0	0
Pakistan	**53**	0	0
Mexico	**25**	1	0
Brazil	0	0	0
South Afri-ca	3	2	0
Kenya	1	**17**	0

Table 61 suggest that *Appliances* projects appear to be less attractive for detailed analysis due to scattered methodological approach, the low number of projects and the limited country coverage. Therefore, household energy efficiency projects will proceed with the following two project groups:

1. *Lighting* projects with methodologies AMS-II.C. & AMS-II.J., with a focus on India, Pakistan and Mexico.
2. *Stoves* with methodologies AMS-I.E. & AMS-II.G., with a focus on India and Kenya.

Annex II - List of Interviewees

The research team gratefully acknowledges the expert input from national experts in various countries, for the enrichment of the analysis:

- N J. Agrawal, project developer, India (Energy efficient lighting in India)
- N Balagurusamy, Universidad Autónoma de Coahuila, Mexico (Commercial livestock manure management in Mexico)
- M. Cazarre, project developer, Brazil (Commercial livestock manure management in Brazil)
- S. Goyal, Project developer, India (Biomass energy in India)
- P. Hauser, Engie Consultants, Brazil (Bagasse power in Brazil)
- I. Hernandez Villegas, Gold Standard, Mexico (Energy efficient lighting in Mexico)
- Prof. V Kishore, TERI, India (Biomass energy in India)
- L. Lasas, Eneko, Brazil (Commercial livestock manure management in Brazil)
- Prof. Dr. Lee Chew Tin, Universiti Teknologi Malaysia (Waste water in Thailand; Waste water in Malaysia; Palm oil solid waste composting in Malaysia)
- A. Mahmood, ENERCON (Energy efficient lighting in Pakistan)
- O. Narayan, project developer, India (Biomass energy in India)
- K. Omer, project developer, Pakistan (Energy efficient lighting in Pakistan)
- S. Padmanabha, Fair Climate (Cook stoves in India; Cook stoves in Kenya; Energy efficient lighting in India)
- Prof. Dr. Pruk Aggarangsi, Energy Research and Development Institute, Chiang Mai University, Thailand (Commercial livestock manure management in Thailand; Waste water in Thailand; Waste water in Malasia)
- G. H. Reddy, project developer, India (Energy efficient lighting in India and Pakistan)
- C.Ricardo Soccol, Federal University of Paraná, Brazil (Bagasse power in Brazil)
- R. Spalding-Fecher, Carbon Limits (Energy efficient lighting in India, Pakistan and Mexico)
- S. Zafar, Bioenergy Consult (Biomass energy in India)

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