



Discussion Paper: CDM Supply Potential up to 2020

Editorial information

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Abstract

This discussion paper estimates the potential supply of certified emission reductions (CERs) from projects registered under the Clean Development Mechanism (CDM) for the period 2013 to 2020. The supply potential estimation considers the most recent information on the status of CDM projects and their ability to issue CERs, if sufficient demand were recreated on short-term. The actual current demand for CERs is still low but could increase if CERs were used beyond the Kyoto Protocol (for example under CORSIA). When considering options for using CERs from registered projects, a key question for policy makers is whether the projects are likely to continue greenhouse gas (GHG) abatement even in the absence of CDM revenues or whether they are vulnerable of discontinuing abatement. Drawing upon recent research, this paper differentiates the CER supply potential between projects that are vulnerable of discontinuing GHG abatement and those that are not. The CER supply potential is estimated based on a bottom-up model that reflects recent research on the status and operation of CDM project activities as well as regulatory requirements of the CDM which could limit the ability to issue CERs, with the view to providing a realistic estimate of the CER supply potential. The CER supply potential for the period 2013 to 2020 is estimated to amount to about 4.7 billion CERs. 82 % of the CER supply potential comes from projects that are not deemed vulnerable, whereas only 4 % comes from projects that are deemed vulnerable but can still issue CERs. For 13 % of the CER supply potential the vulnerability is variable; for 2 % it was not assessed. Although this potential is significant, it is considerably lower than the ex-ante emission reduction estimates in project design documents of 7.7 G t CO₂e for the same period. Hydro and wind power projects contribute most to this potential, making up 61 % of the overall CER supply potential. The relative contribution of industrial gas projects is with 8 % much lower than in the first commitment period where they accounted for 52 % of the CERs issued. Programmes of activities (PoAs) only account for 3 % of the potential.

Kurzbeschreibung

Dieses Diskussionspapier berechnet für den Zeitraum von 2013 bis 2020 das Potenzial für die Ausgabe von Zertifikaten aus Projekten, die unter dem Clean Development Mechanism (CDM) registriert wurden. Die Abschätzung des Potenzials basiert auf aktuellen Informationen zum Status von CDM-Projekten und ihrer Möglichkeit, Zertifikate auszugeben, wenn kurzfristig neue Nachfrage geschaffen wird. Die Nachfrage nach CDM-Zertifikaten ist derzeit noch niedrig. Sie könnte sich jedoch erhöhen, wenn CDM-Zertifikate auch außerhalb des Kyoto-Protokolls (wie insbesondere im Luftverkehr unter CORSIA) genutzt werden. Wenn eine solche Nutzung erwogen wird, ist für Entscheidungsträger eine wichtige Frage, ob die Projekte auch ohne CDM-Zertifikate die Minderung der Treibhausgase fortsetzen, oder ob sie gefährdet sind, die Minderung einzustellen. Auf Basis von aktuellen Forschungsergebnissen wird in diesem Papier das Potenzial separat für gefährdete und nicht gefährdete Projekte ausgewiesen. Das Potenzial wird mit Hilfe eines Modells berechnet, das den aktuellen Forschungsstand zum Status von CDM-Projekten und mögliche regulatorische Einschränkungen für die Ausgabe von Zertifikaten berücksichtigt. Hierdurch soll ein realistisches Potenzial abgeschätzt werden. Das Papier kommt zu dem Ergebnis, dass für den Zeitraum von 2013 bis 2020 etwa 4.7 Milliarden Zertifikate ausgegeben werden könnten. 82 % dieses Potenzials kommt von Projekten, die als wenig gefährdet eingestuft werden, die Minderung einzustellen. Lediglich 4 % des Potenzials kommt von Projekten, die als gefährdet gelten, aber noch Zertifikate ausgeben können. Für 13 % ist die Gefährdung variabel und für 2 % wurde sie nicht bestimmt. Das Potenzial ist insgesamt groß, aber deutlich niedriger als die Annahmen der Projektentwickler bei der Genehmigung der Projekte, die aggregiert bei 7.7 G t CO₂e für den gleichen Zeitraum liegen. Wasser- und Windkraftwerke machen mit 61 % der Zertifikate den größten Anteil aus. Projekte zur Vermeidung von Industriegasen haben mit 8 % einen niedrigeren Anteil als in der ersten Verpflichtungsperiode des Kyoto-Protokolls, in der sie 52 % der Zertifikate ausgegeben haben. CDM-Programme (PoA) tragen nur mit 3 % zum Potenzial bei.

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List of Abbreviations

CDM	Clean Development Mechanism
CER	Certified emission reductions
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CPA	Component project activity
EE	Energy efficiency
EU	European Union
GHG	Greenhouse gas
HFC	Hydrofluorocarbon
INDCs	Intended nationally determined contribution
NDC	Nationally determined contribution
PDD	Project design document
PFC	Perfluorocarbon
PoA	Programme of activities
t CO₂e	Tonnes of CO ₂ equivalent
UNFCCC	United Nations Framework Convention on Climate Change

1 Introduction

Under the Clean Development Mechanism (CDM), more than 8,000 projects or programmes of activities (PoAs) were registered as of April 2017. This large number has led to an increasing supply of certified emission reductions (CERs), which in recent years superseded the demand for such credits. Demand has tailed off considerably due to the global economic crisis, a stronger focus on domestic mitigation action, criticisms with regard to transaction costs and environmental integrity of the mechanism, as well as the uncertainty of possible future use. The discourse between supply and demand has had a dramatic effect on the price of CERs, which has plummeted in recent years.

As a consequence of these developments, many project owners no longer have revenues from CERs. Some project developers have gone bankrupt, and some registered projects were never implemented or were dismantled. The majority of projects stopped verification of emission reductions and issuance of CERs, and some stopped monitoring the greenhouse gas (GHG) emission reductions altogether. For about 1,000 registered projects, the first crediting period has ended, but only a third of them have renewed their crediting period yet. Nevertheless, the available research suggests that the large majority of registered CDM projects continue GHG abatement even without CER revenues, whereas some projects face a considerable risk of discontinuing or have already discontinued GHG abatement (Schneider & Cames, 2014; Warnecke et al., 2017; Warnecke, Day, & Klein, 2015).

At the same time, new demand for CERs could arise from different sources:

- ▶ In October 2016, the International Civil Aviation Organization adopted a resolution establishing a Carbon Offsetting and Reduction Scheme for International Aviation (CORSA). The scheme aims to reach neutral emissions growth from 2020 levels. The resolution establishes that, under certain conditions, emissions units generated from mechanisms established under the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement are eligible for use in CORSA. Key design questions include which project types from which mechanism will be eligible and which vintage of emission reductions will be recognized.
- ▶ Some countries recognize or intend to recognize CERs as a means of compliance in national mitigation policies. For example, South Korea recognizes domestic CERs in its emissions trading system. Mexico passed initial legislation to recognize CERs for meeting carbon tax obligations, and South Africa has advanced plans to do so in its tax. In the EU, CERs may be recognized as a compliance instrument under the Fuel Quality Directive.
- ▶ With the adoption of the Paris Agreement, more than 190 countries have submitted nationally determined contributions (NDCs)¹ which specify their proposed mitigation targets or actions after 2020. In negotiations under the UNFCCC, some Parties have proposed that CERs should be recognized towards achieving NDCs; however, no agreement has been achieved on this matter so far.
- ▶ Development cooperation agencies consider purchasing CERs as a means to effectively disburse results-based climate finance, including for closing the pre-2020 mitigation gap. For example, the World Bank's Pilot Auction Facility for Methane and Climate Change Mitigation established a pay-for-performance mechanism which uses auctions to allocate public funds to projects that are vulnerable of discontinuing GHG abatement.²
- ▶ Several initiatives aim to increase demand for voluntary offsetting GHG emissions, including the United Nations online platform for voluntary cancellation of CERs.³

These developments could potentially create demand and a price signal for CERs for some (types of) CDM projects. This raises two important questions:

1. How many CERs from already registered projects could be issued for emission reductions up to 2020, noting the uncertainty surrounding the current status of implementation of projects and taking into account the CDM rules for issuing CERs?

1 In the preparation of the COP21 in December 2015 in Paris, most countries submitted intended nationally determined contributions (INDCs). Once a country ratifies the Paris Agreement, the INDC becomes the country's NDC – unless the Party determines otherwise. Although Parties can still update their INDCs in light of the adopted Agreement during the ratification process, most INDCs will likely remain unchanged. In this paper, we use the term NDCs to reflect both NDCs and INDCs that have not yet been converted into NDCs.

2 <https://www.pilotauctionfacility.org>

3 <https://offset.climateneutralnow.org>

2. How much of this potential CER supply would come from projects that would continue GHG abatement even without CER revenues, and how much from projects that are at risk of discontinuing GHG abatement without ongoing CER revenues?

Both questions are important considerations for policy makers deliberating the recognition or purchase of CERs. The first question allows understanding how the CER supply relates to any new demand. This could help avoid a strong imbalance between supply and demand, as experienced under the CDM and JI. The second question allows understanding the GHG emission impact of creating new demand for CERs, i.e. whether new demand triggers further emission reductions or whether these reductions would also occur in the absence of the new demand.

This paper addresses both questions. We estimate the CER supply potential from registered projects for the period 2013 to 2020, differentiated by projects that are vulnerable of discontinuing GHG abatement and those that are not. The CER supply potential is estimated based on a bottom-up model which draws upon different information sources, including information on specific projects, on project types and on country context, where available. The issue of whether or not projects are deemed not being vulnerable does not affect prior assessments of additionality at project start but just looks to the current status of projects.

We aim to provide a realistic estimate of the CER supply potential – we do not provide an estimate of the likely actual CER issuance under the current conditions. The actual issuance of CERs depends on CER demand and prices. Investigation of this relationship is out of the scope of this paper and will require to be analysed in a future paper. Here we estimate the potential, assuming that project owners would have sufficient incentives to proceed to issuance.

Previous estimates of the CER supply potential for the period up to 2020 vary significantly (Bailis, Broekhoff, & Lee, 2016; Cames, 2015; IGES, 2017; UNFCCC, 2017b; Warnecke, Day, & Klein, 2015; Warnecke, Day, & Tewari, 2015; World Bank, Ecofys, & Vivid Economics, 2016). All estimates are based on data from the CDM project portfolio. However, assumptions vary strongly, in particular with regard to whether „dormant“ projects, i.e. projects which are currently not issuing or have not yet issued CERs, can or will do so in the future. Some authors aim to estimate a maximum CER supply potential (Bailis et al., 2016; Cames, 2015; UNFCCC, 2017a; Warnecke, Day, & Tewari, 2015; World Bank et al., 2016), some provide an estimate of the likely CER issuance under current market conditions (IGES, 2017; Warnecke, Day, & Tewari, 2015; World Bank et al., 2016). Some studies consider, to a varying degree, projects in the pipeline which have not yet been registered (Bailis et al., 2016; IGES, 2017; UNFCCC, 2017a), others consider only registered projects (Cames, 2015; Warnecke, Day, & Tewari, 2015; World Bank et al., 2016).

Our estimates differ in three important aspects from most previous estimates. First, we combine CDM project portfolio information with the latest available research on the implementation status of projects and on CER supply from specific sectors. This includes research on the implementation status of the projects, e.g. whether the projects have been implemented and whether they continue GHG abatement and continuously monitor emission reductions, as well as detailed estimates of the CER supply potential for industrial gas projects (Schneider & Cames, 2014; Warnecke, Day, & Klein, 2015). Second, we consider in detail the regulatory requirements of the CDM which could facilitate or limit the ability of project owners to issue CERs. This includes, for example, the possibility to change focal points that have ceased to exist, the possibility to request for temporary deviations or permanent changes to a registered monitoring plan, or the consequences of a delayed renewal of a crediting period. Third, we estimate the CER supply potential separately for projects that are vulnerable of discontinuing GHG abatement and those that are not, drawing upon relevant research (Schneider & Cames, 2014; Warnecke et al., 2017). In this context, it is important to note that the fact that a project is not deemed vulnerable of discontinuing GHG abatement does not contest the assessment of additionality at project inception. Rather, it recognises that, from a today's perspective, the project's savings or revenues from continued operation exceed its operational expenditures. Therefore, the distinction between vulnerable and non-vulnerable projects does not relate to the quality of the projects as such, but it has implications for the GHG emissions impact of purchasing or recognising CERs from these projects.

Our estimates of the CER supply potential only include registered projects. The full CER supply potential is thus larger: it would include existing projects that have initiated validation in the past, but did not proceed to registration due to the market situation, as well as new projects that could be newly developed.

We limit the analysis to registered projects for two reasons: first, it is very uncertain how many new projects could be developed and how many of the projects that are still under validation could proceed to registration. Second, developing new projects requires lead times, which limits the CER supply potential from new projects in the period up to 2020.

Below we first introduce the methodology and assumptions used to estimate the CER supply potential and to assess which projects are vulnerable of discontinuing GHG abatement (section 2). We then present our estimates of the CER supply potential (section 3), followed by conclusions and recommendations (section 4). More detailed information on data sources and assumptions used for the methodology is presented in an Annex for further reference.

2 Methodological Approach

2.1 CER supply potential

We estimate the CER supply potential from registered CDM projects based on a bottom-up model that assesses the potential CER issuance for each of the over 8,000 registered projects and programmes of activities (PoAs). The model combines information from individual projects with information on project types and the context of the host country, where available. The CER supply potential is estimated for each year from 2013 to 2020. For periods for which CERs have already been issued, UNFCCC data on the actual issuance is used. For periods or projects without issuance, we estimate the potential CER issuance using the methodology described below. For PoAs, we determine the CER supply potential of the PoA by aggregating the information from all individual component project activities (CPAs) that have been included in the PoA as of 12 April 2017. We determine the CER supply potential separately for projects that are deemed vulnerable of discontinuing GHG abatement, for those that are not, and for those where the vulnerability is variable or uncertain, depending on the specific circumstances of the project.

To estimate the CER supply potential, we assess for each project how many CERs can be issued for which time period. Several circumstances could limit the ability of registered projects to issue CERs, including the technical status of the project and relevant CDM requirements. We use the most recent available information to evaluate the technical status and the impact of relevant CDM requirements for each individual project. In February 2017, the CDM Executive Board revised key regulatory documents which become effective as of 1 June 2017.⁴ The revision is the result of a two-year simplification process that enhances flexibility for project participants in various ways, in particular for PoAs. We reflect this recent revision in estimating the CER supply potential.

Key aspects affecting the CER supply potential

We identify and reflect in our model four key aspects that affect the amount of and the period for which CERs can be issued:

- 1. Technical implementation and operation status:** The initial implementation and subsequent operation of a project is a key prerequisite for issuing CERs. Most CDM projects are known to have been implemented; yet some projects were registered but never implemented, due to low CER prices or other reasons such as technical implementation problems. Many projects also faced delays in implementation which affects the amount of CERs they can generate until 2020. Most implemented projects continue GHG abatement, whereas some have either discontinued abatement or are at the risk of discontinuing abatement. Among the projects that have discontinued GHG abatement, some could potentially resume abatement at a later point in time, if they have incentives to do so. To assess the implementation status of projects, we draw upon project specific information and relevant research on the implementation status for different project types and countries where available (see Annex A1 for more details).

⁴ Version 1.0 of the „CDM project standard for project activities“, the „CDM validation and verification standard for project activities“, the „CDM project cycle procedure for project activities“, the „CDM project standard for programmes of activities“, the „CDM validation and verification standard for programmes of activities“ and the „CDM project cycle procedure for programmes of activities“.

2. **Crediting periods:** Under the CDM, project participants can choose between a fixed or a renewable crediting period. In principle, projects with renewable crediting periods can generate CERs for emission reductions occurring from the start of the first crediting period until the end of the last crediting period; yet for that to take place, administrative for the renewal of the crediting period have to be taken 180 days before the previous crediting period ends. If these steps are not taken in time, CERs cannot be issued for a certain period. We find in our analysis that more than 1,000 projects have not taken these steps in time, most likely due to the current market situation. The renewal of crediting periods can also impact the methodological approaches used to calculate emission reductions, as included in baseline and monitoring methodologies, methodological tool and standardized baselines. The methodological approaches to determine emission reductions are usually fixed for a crediting period. At the renewal of a crediting period, the project participants have to update the methodological approaches and data used to calculate emission reductions, using a methodology version that is valid at the time of renewal. In some instances, methodological approaches to calculate emission reductions have been revised substantially over time, altering the amount of emission reductions that projects can claim in subsequent crediting periods. We identify for each project the duration of crediting periods and how CDM requirements for crediting period renewal affect the project's ability to issue CERs and the methodological approaches to calculate emission reductions (see Annex A2 for more details).
3. **Availability of data to monitor emission reductions:** Monitoring emission reductions is a further prerequisite for issuing CERs. In the current market situation, many projects continue monitoring emission reductions but do not issue CERs, whereas others have stopped collecting data for CDM monitoring purposes. We assess which projects are likely to continue collecting relevant monitoring data and how CDM monitoring requirements affect their ability to issue CERs (see Annex A3 for more details).
4. **Project performance:** How many emission reductions a project generates also depends on its performance, such as how much electricity is generated by a wind power plant or how much methane is captured from a landfill. For many projects the actual performance is different from the performance expected when registering the project. We therefore use data on the project performance of different project types to estimate the CER supply (see Annex A4 for more details).

A further prerequisite for issuing CERs is that the project participants still exist. Under the CDM, project participants assign focal points that are responsible for communicating with the UNFCCC secretariat and requesting the issuance or forwarding of CERs. Currently, some CDM projects are unable to issue CERs because a focal point does not exist anymore, e.g. due to bankruptcy.⁵ In the recent revision of regulatory documents by the CDM Executive Board, one important simplification is more flexibility to change focal points. Under the new rules, project participants have additional means to address such situations, including that the remaining project participants can remove a focal point that has ceased to exist. We therefore assume here that current limitations in issuing CERs due to inactive or non-existent focal points can be addressed under the new rules and that the current problems will not limit the issuance of CERs in the future, noting that there could be few instances where this is not possible.

Methodology to assess whether and for which time period CERs can be issued

Figure 1 presents the methodology used to assess whether and for which time period projects can issue CERs. The flow chart identifies nine circumstances (questions 1 to 9) which can impact the ability to issue CERs over time, and seven possible outcomes (A to G) for the period for which CERs can be issued.

⁵ According to UNFCCC (2015), 20 % of the emails sent to all primary and secondary focal points in 2015 never reached the recipient, as confirmed by an automatic reply for invalid e-mail addresses.

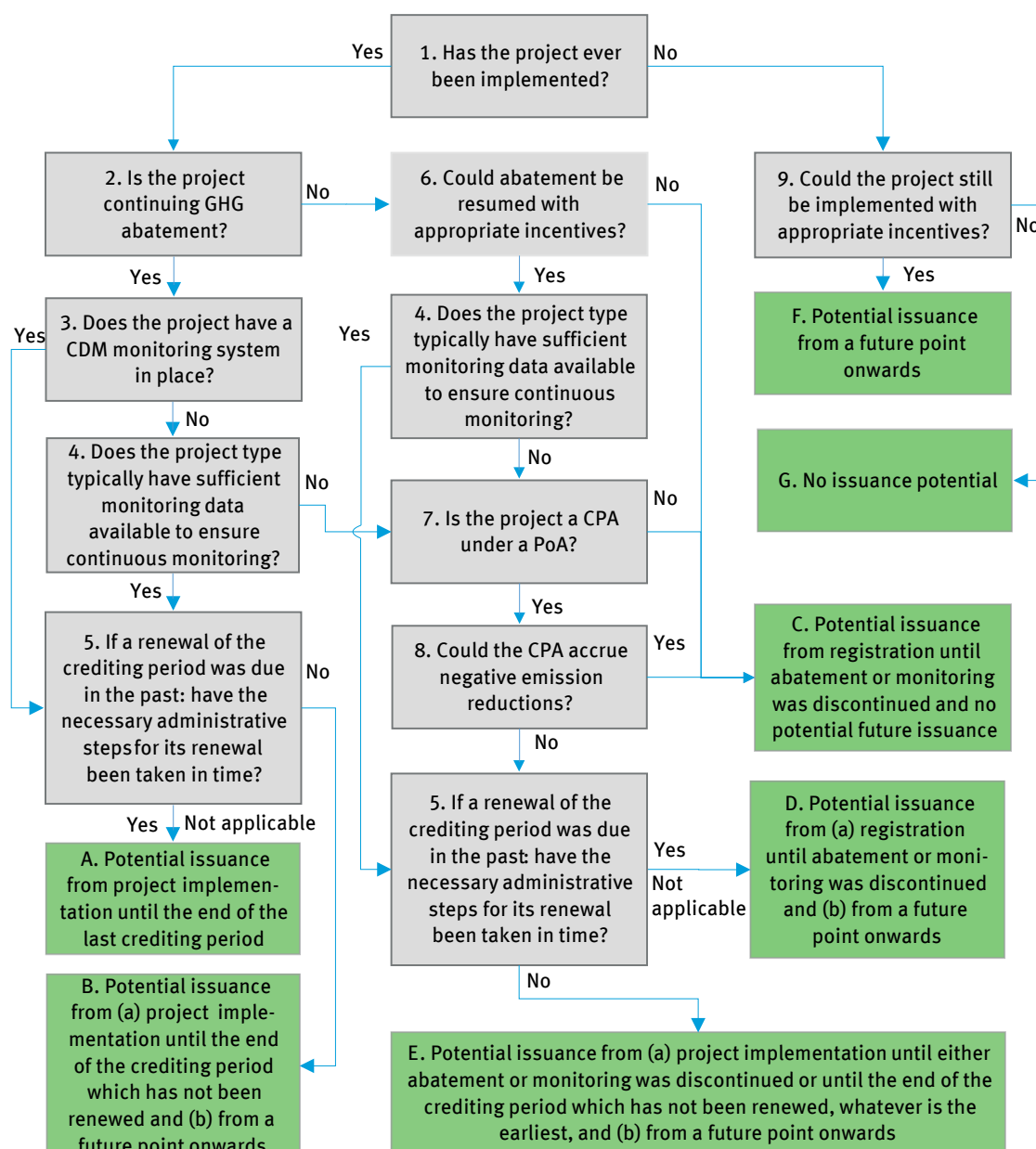


Figure 1: Methodological approach to assess the time period for which projects can issue CERs

For a project to issue CERs for emission reductions from its implementation until the end of its last crediting period (outcome A), several conditions have to be met:

- ▶ First, the project must have been implemented (question 1).
- ▶ Second, the project must continue GHG abatement (question 2).
- ▶ Third, it must be able to continuously monitor emission reductions (questions 3 and 4).
- ▶ Fourth, in case that a renewal of the crediting period was due in the past, the project must have taken in time the necessary administrative steps to renew its crediting period (question 5).

In all other cases, the projects can either not issue CERs at all, or only issue CERs in part of the period 2013 to 2020.

If a project was never implemented, a key question is whether it could still be implemented with appropriate incentives or whether the project could not be implemented any longer, for example because it does not hold the necessary permits or is technically not feasible (question 9). If the project could still be implemented, it could start issuing CERs from a future point onwards (**outcome F**). If the project could not be implemented any longer, it cannot issue any CERs (**outcome G**).

If a project was implemented but subsequently discontinued GHG abatement, a key question is whether abatement could be resumed (question 6). If abatement cannot be resumed, CERs can only be issued from the project start until abatement was discontinued (**outcome C**). If abatement can be resumed, several CDM requirements come into play. Generally, the CDM requires continuous monitoring of emission reductions. A first important question is therefore whether sufficient monitoring data is typically available for that project type to ensure continuous monitoring even though GHG abatement has temporarily stopped (question 4). For example, if a wind power plant has temporarily stopped operation, electricity meters may still be in place to ensure continuous monitoring. By contrast, a methane avoidance project may not be able to continuously monitor emission reductions if the GHG abatement has stopped. The consequences differ:

- ▶ If sufficient monitoring data is available to ensure continuous monitoring of emission reductions (question 4), the project could start issuing CERs again at a future point in time. However, rules governing the renewal of crediting periods could limit the possibility to issue CERs (question 5), resulting in different potential outcomes for the duration of crediting (**outcomes D and E**).
- ▶ If sufficient monitoring data is not available to ensure continuous monitoring of emission reductions (question 4), the consequences differ between project activities and CPAs under PoAs (question 7): A CDM project that has stopped continuous monitoring can no longer issue CERs, even it would resume abatement (**outcome C**). By contrast, monitoring can be interrupted for CPAs: a CPA could be excluded when abatement discontinues and be re-included in a PoA or be registered as a separate project when abatement is resumed, as long as it cannot accrue negative emission reductions, e.g. due to significant leakage effects (question 8). We thus assume here that PoAs that are not able to monitor emission reductions for their CPAs in recent years could resume to do so in the future and re-start issuing CERs at a future point in time, except if the methodology can potentially accrue negative emission reductions (**outcomes D or E**).⁶ If the CPAs can accrue negative emission reductions, we assume that no further issuance of CERs is possible, beyond the amounts that were already issued (**outcome C**).

If a project was implemented and continues GHG abatement but is not able to monitor emissions reductions, similar considerations apply with regard to CDM requirements as when GHG abatement was stopped (questions 5, 7 and 8, outcomes C, D and E). Finally, if a project was implemented, continues GHG abatement, and is able to monitor emission reductions, the issuance of CERs could still be limited if the project has not taken the necessary administrative steps to renew their crediting period (question 5, outcome B).

The flow chart in Figure 1 illustrates that in several instances issuance is temporarily not possible but could be resumed „at a future point in time“. This relates to situations where projects still have to be implemented, where GHG abatement or monitoring of CPAs has to be resumed, or where administrative steps have to be taken to renew the crediting period. Taking these actions requires lead times, including for technical implementation and for administrative steps such as preparing and validating documents needed for the renewal of a crediting period. Noting that lead times can be significant, and that a price signal to take such action does not yet exist, we assume that these projects could re-start issuing CERs for emission reductions generated as of 1 January 2019.

Data and information used to calculate the CER supply potential

In some instances, we have sufficient information to clearly answer a question in Figure 1 at the level of an individual project. For example, if a project has issued CERs, it is known that it has – at least initially – been implemented. In other instances, however, we only have information and data at a more aggregated level, such as information from surveys. In these cases, we use this information to assign a probability to the answer of a question. For example, if a survey would indicate that 80 % of biomass projects have ever been implemented (question 1), 80 % of the CER potential from a biomass project would be carried forward to question 2 (assessing continuation of abatement activity) and 20 % would be carried forward to question 9 (assessing ability of non-implemented projects to become implemented). The outcome for each individual project is thus a probability distribution across the eight possible outcomes. For example, a project could have 60 % probability of outcome A, a 30 % probability of outcome C and a 10 % probability of outcome D. This probability distribution is then used to calculate the CER supply potential of each individual project over time.

⁶ The list of relevant methodologies is included in Appendix 3 of version 01.0 of the CDM project cycle procedure for project activities.

We use three main data sources to apply this methodology:

- ▶ First, for project specific information, we mainly use a database published and regularly updated by the UNFCCC secretariat (UNFCCC, 2017b). This database aggregates and contains publicly available information from project design documents (PDDs), monitoring reports and other administrative actions taken by projects. We use this database because it is authoritative and consistent with the information system maintained by the UNFCCC secretariat. Information used from this database includes, inter alia, data on ex-ante calculation of emission reductions, actual CER issuance, and the crediting period lengths and renewal status.
- ▶ Second, to assess the probability of different possible outcomes in Figure 1, a key resource is the survey conducted by Warnecke, Day, & Klein (2015). We use the survey responses to assess questions 1, 2, 3 and 6 in Figure 1. Table 1 summarizes the survey results by project type for questions 1, 2 and 3; further information on how question 6 is answered is provided in the Annex. The project types included in the survey cover 82 % of the registered projects. The results by Warnecke, Day, & Klein (2015) broadly match those of a survey conducted by the UNFCCC secretariat in 2015 (UNFCCC, 2015). According to the UNFCCC survey, only 7 % of the projects were not implemented. For 5 % of the projects construction had started. 86 % of the projects responded that they were operating, and only 2 % were either abandoned or not operating.
- ▶ Third, for industrial gas projects, we also use the detailed project-specific estimates of the emission reduction volume developed by Schneider & Cames (2014). These estimates consider the plant-specific performance, as well as specific methodological requirements in the relevant methodologies, including changes at the renewal of the crediting period. We use this data source because it allows a more accurate estimate for industrial gas projects. Both the project performance and the renewal of crediting period have considerable impact on the CER supply potential from industrial gas projects. Schneider & Cames (2014) reflect the impact of these two factors for each project.

In combining these different data sources, we ensure that they are used coherently. For example, when we use project-specific information for projects where it is publicly available and information from surveys for the remainder of the projects, we ensure that the aggregated assessment for all projects is consistent with the survey data. For this purpose, we calculate for the data in Table 1 an adjusted probability that is only applicable to those projects where project-specific information on the relevant question is not available, such that the probability for all projects in a category, including those for which project-specific information is available, matches the results presented in the table. In the Annex, we explain in further detail how we assess the four key aspects identified above, including the eight circumstances in Figure 1 above.

Table 1: Status of projects by project type, based on Warnecke, Day, & Klein (2015)

Project type	Share of projects that have ever been implemented ^{a)}	Share of implemented projects that continue abatement ^{b)}	Share of implemented and abating projects that have a CDM monitoring system in place ^{c)}
Biomass energy: Agriculture and forestry residues	95 %	82 %	83 %
Biomass energy: Bagasse power	97 %	68 %	29 %
Biomass energy: Palm oil solid waste	100 %	83 %	50 %
Cement: Clinker	100 %	81 %	100 %
Coal mine methane	100 %	91 %	67 %
EE households: Stoves	83 %	100 %	83 %
EE households: Lighting	68 %	83 %	96 %
EE Industry	94 %	87 %	66 %
EE own generation: Coke oven gas / iron & steel heat	99 %	88 %	81 %

Project type	Share of projects that have ever been implemented ^{a)}	Share of implemented projects that continue abatement ^{b)}	Share of implemented and abating projects that have a CDM monitoring system in place ^{c)}
EE own generation: Cement heat	100 %	100 %	100 %
Fossil fuel switch: Oil to natural gas	100 %	87 %	80 %
Fossil fuel switch: New natural gas plant	100 %	81 %	87 %
Micro hydro (<2MW)	97 %	71 %	77 %
Hydro 2-20MW	98 %	99 %	95 %
Landfill gas: Flaring	85 %	62 %	82 %
Landfill gas: Power generation	93 %	79 %	83 %
Methane avoidance: Flaring	98 %	36 %	73 %
Methane avoidance: Power generation	96 %	79 %	75 %
Methane avoidance: Composting	70 %	69 %	81 %
Methane avoidance: Domestic manure	94 %	94 %	100 %
N ₂ O: Adipic acid	100 %	100 %	50 %
N ₂ O: Nitric acid	100 %	49 %	93 %
HFC-23	100 %	69 %	77 %
Solar photovoltaic	97 %	99 %	76 %
Solar water heating	100 %	59 %	100 %
Wind	99 %	98 %	95 %
Global average	97 %	90 %	89 %

Note: The answer „I don't know“ was excluded from totals.

a) The share has been determined based on the answers: „Fully implemented“, „Implementation / construction started“, „Investment decision made“, „Dismantling of project activity“.

b) The share has been determined based on the answers „in regular operation“ and „No CDM-conformant operation, alternative GHG mitigation equipment operating“.

c) The share has been determined based on the answer „implemented and operational“.

2.2 Project Vulnerability of Discontinuing GHG Abatement

This section provides an overview of project vulnerability for the discontinuation of GHG abatement, based on Warnecke et al. (2017). The information is used in this report to estimate the CER supply potential separately for projects with high, low and variable or uncertain vulnerability to discontinuation.

Warnecke et al. (2017) developed a methodology for the assessment of the vulnerability of existing CDM projects for the discontinuation of GHG emission abatement. The methodology employs a systematic approach to assess the likelihood of project continuation, for any given project, based upon the following aspects:

- ▶ **Applicable laws and regulations:** laws and regulations in host countries might have a direct influence on the conditions of the project activity and the feasibility of the identified scenarios, for example by explicitly requiring the continuation of the project activity, or by outlawing other practices which might cause the continuation of the activity to be the only feasible option. In Warnecke et al. (2017), the analysis did not take consideration of the extent to which such regulations are implemented and enforced: 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.

- ▶ **Economic benefits and costs:** in the absence of significant CER revenues, the continuation of project activities is heavily influenced by the net financial flows that occur as a result of the project's continued operation. Such flows may include operational costs, maintenance costs, and any other appropriate costs, as well as financial benefits such as potential direct revenues or cost savings generated by project outputs. In Warnecke et al. (2017), the costs and benefits mapped included 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 were 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. The vulnerability for discontinuation is considered higher in the case that the economic conditions for continuation are considered to be negative (where the ongoing additional costs exceed any additional financial benefits).
- ▶ **Barriers and other conditions:** 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 those 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. On the other hand, it may also be that mitigating factors might increase the plausibility of scenarios deemed to have negative economic conditions; such factors may include, for example, that the project owner is motivated by other non-financial considerations, perhaps such as research or community development programmes.

Figure 2 provides an overview of the project vulnerability assessment methodology applied in Warnecke et al. (2017), upon which the analysis of this report is based, and where full methodological details can be found.

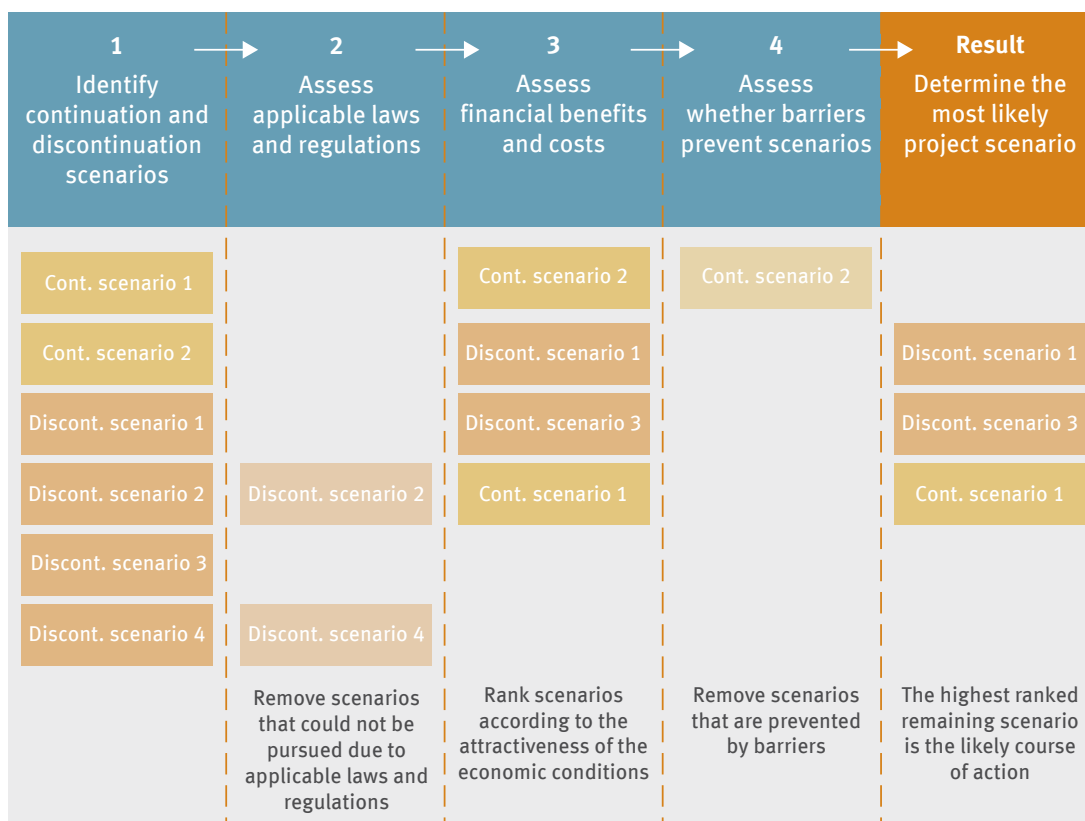


Figure 2: Decision chart used for the assessment of the risk that different CDM project types stop GHG abatement. Source: Warnecke et al. (2017)

Table 2 presents an overview of the estimated vulnerability for project discontinuation for all major CDM project types. The information is based on the analysis conducted by Warnecke et al. (2017), insights from Schneider & Cames (2014), as well as supplementary insights from the authors of this report. The vulnerability to discontinuation of the project types is indicated in the table with the following general classifications:

- ▶ **High vulnerability:** The majority of projects within the project type are understood to be at risk of discontinuation without alternative support.
- ▶ **Low vulnerability:** The conditions of the majority of projects within the project type are such that the continuation of the project activity is likely to continue even in the absence of continued CER revenues or alternative support.
- ▶ **Variable vulnerability:** The conditions that determine the feasibility and attractiveness of project continuation and discontinuation scenarios are highly variable across projects due to high dependence on local conditions and/or specific individual circumstances, such that a generalised classification of project vulnerability is not possible.
- ▶ **Unknown vulnerability:** The discontinuation risk of the project type has not been assessed.

For most project types, the vulnerability classification is given at the level of the project type and for all host countries. For some project types with variable vulnerability, further information is given for important project sub-types and specific countries for which information is available, based on the detailed analysis of specific sub-types for Warnecke et al. (2017), as well as insights from Schneider & Cames (2014) and the Multilateral Fund for the implementation of the Montreal Protocol (UNEP, 2017).

The classifications in Table 2 represent generalisations of typical project situations. Conditions and prospects for individual projects may vary from these categorical generalisations, which offer orientation only for aggregated analysis.

It has however to be considered that any classification of project vulnerability does not necessarily indicate a lack of additionality at project start as the classification just looks at the current status.

Table 2: Overview of vulnerability for project discontinuation for assessed project types, based on Warnecke et al. (2017)

Project type <i>Including a description of subproject types where additional information is available (this does not include an exhaustive list of included subtypes)</i>	Project vulnerability
<p>Biomass energy Use of biomass-based fuels, such as agricultural and forestry residues, biogas and biodiesel, for energy generation</p> <p style="text-align: center;"><i>Bagasse power</i></p> <p style="text-align: center;"><i>Biomass independent power producers (IPPs) and captive biomass energy</i></p>	<p>Variable according to subtype and local conditions</p>
	<p>Low: Usually a low risk activity due to the highly positive economic conditions from the utilisation or sale of electricity to the grid (e.g. detailed analysis confirms this case for projects in India and Brazil).</p>
	<p>Variable: Highly variable depending upon local market conditions for biomass and grid connectivity regulation. High vulnerability in some areas of India due to competition for biomass and the unreliable biomass supply; low vulnerability in Thailand.</p>
<p>Coal mine / bed methane Treatment and/or utilisation of methane from coal mines, including ventilation air methane</p>	<p>Low: Financial benefits for power generation from methane utilisation often exceed operating expenditures.</p>

Project type <i>Including a description of subproject types where additional information is available (this does not include an exhaustive list of included subtypes)</i>	Project vulnerability
EE households Lighting, stoves and appliances <i>Lighting</i> <i>Cooking stoves</i>	Variable according to subtype and local conditions Low: Despite disengagement of project owners, regulations often require continued use of lightbulbs (e.g. Mexico), whilst decreasing costs and increasing awareness of benefits makes their continued use likely even in the absence of regulation (e.g. Pakistan and India). High: Disengagement of third party project owners. Barriers related to the affordability of new stoves, knowledge of benefits and cultural preferences may prevent continued use despite potentially being economically beneficial for owners.
EE industry Efficiency improvement in industrial plant processes	Low: Significant cost savings with no or low additional OPEX
EE own generation Use of process wastes for heat or energy generation	Low: Significant cost savings with no or low additional OPEX
EE supply side Efficiency improvements of existing energy generation facilities incl. fossil fuel plants, cogeneration and combined cycle projects	Low: Significant cost savings with no or low additional OPEX
Forests Afforestation, reforestation, mangroves and agroforestry	Variable according to capacity of owner and local legislation
Fossil fuel switch New natural gas plants and switch from oil to natural gas	Variable according to project subtype and global fuel markets
Fugitive Treatment of fugitive gases from oil and gas production	Variable according to project subtype
Geothermal	Low: Significant revenues and very low OPEX
HFCs Treatment of HFC23 waste gases <i>HFC23 in China and India</i> <i>HFC23 in other countries</i>	Low due to domestic policies to incentivize abatement High: OPEX incurred yet no significant financial benefits. Uncertain when emissions will be addressed under the Kigali Amendment to the Montreal Protocol.
Hydro	Low: Significant revenues and very low OPEX
Landfill gas Treatment of landfill gas and municipal solid waste including flaring and power generation activities	Variable according to subtype and local conditions

Project type <i>Including a description of subproject types where additional information is available (this does not include an exhaustive list of included subtypes)</i>	Project vulnerability
Methane avoidance Avoidance, treatment and utilisation of methane from manure, wastewater, palm oil waste and composting <i>Commercial livestock manure management</i> <i>Waste water</i> <i>Palm oil solid waste composting</i>	Variable according to subtype and utilisation of wastes and methane Variable: Continuation is economically rational in the absence of barriers. Low vulnerability in Thailand. High vulnerability in Mexico and Brazil, where farmers do not have capacities to continue in the absence of third party project owners. Low: Revenues and cost savings from energy generation greater than operating expenditures. Common practice in India, Malaysia and Thailand, even outside of CDM. Variable across local regions, depending on the maturity of the market for alternative uses of palm oil processing residues
N₂O Decomposition of N ₂ O from nitric and adipic acid production <i>N₂O in South Korea and Brazil</i> <i>N₂O in other countries</i>	Low: Specific situation for projects in these countries understood High: Incurs OPEX but no or very low financial benefits
PFCs+SF₆ Avoidance, treatment or recycling PFC and SF ₆ gases	Low (AM78) - High (AM35/65): No revenues but additional OPEX for projects using methodologies AM35/AM65
Solar Solar PV, solar thermal and solar water heating	Low: Non-CER revenues usually greater than OPEX
Other project types	Unknown vulnerability

3 Discussion of Results

3.1 Total CER Supply Potential

Applying the methodological approach described in section 2, the **total CER supply potential** from registered projects for the period 2013 to 2020 is estimated to amount to **4.7 billion CERs**. This estimate is based on projects and CPAs that were approved as of 12 April 2007 and reflects the current regulatory requirements of the CDM and the current knowledge about the status and operation of CDM projects. It does not reflect the likely actual expected issuance under current market conditions, but represents the amount of CERs that could be issued if new demand arises and project owners have sufficient incentives to continue or resume GHG abatement, monitor emission reductions, and proceed to issuance. Over time, the total CER supply potential for the period may increase – if new projects were registered or new CPAs included – or decrease – if due to the current market conditions further projects discontinue GHG abatement or do not resume GHG abatement.

The total CER supply potential is considerable, in particular compared to current levels of issuance and demand. The potential CER supply for the period 2013 to 2020 exceeds more than twice the total amount of CERs issued to date (1.8 billion), and exceeds more than ten times the CERs issued for the second commitment period to date (337 million). It is also much larger than the likely remaining demand in the second commitment period which has been estimated by the UNFCCC secretariat to amount to 77 million CERs per year in the period up to 2020 (UNFCCC, 2016).

Table 3: Factors contributing to a lower CER supply potential than the emission reductions anticipated in PDDs

	Billion CERs	%
Ex-ante estimates in PDDs	7.67	
Contribution of different limitations	-3.01	100 %
Lower actual issuance	-1.90	63 %
Non-implementation of projects	-0.10	3 %
Non-continuation of GHG abatement	-0.42	14 %
Availability of data to monitor emission reductions	-0.33	11 %
No administrative steps taken in time to renew the crediting period	-0.27	9 %
CER supply potential	4.65	

Although the overall CER supply potential is significant, it is considerably lower than the ex-ante emission reduction estimates in PDDs, which aggregately correspond to emission reductions of about 7.7 G t CO₂e for the period 2013 to 2020. Table 1 illustrates the contribution of different factors that limit CER issuance compared to the ex-ante expectations in PDDs. The most important factor is a lower than anticipated rate of issuance success, which could occur due to delayed implementation of projects, a worse than anticipated project performance, conservative adjustments when monitoring emission reductions, the use of different methodological approaches for ex-ante and ex-post emission reduction calculation, and the use of more conservative methodologies after the renewal of the crediting period. Among the other factors, the non-continuation of GHG abatement, the availability of data to monitor emission reductions, and the lack of administrative steps to renew the crediting period are important, whereas the non-implementation of projects has only a minor impact.

Table 4 compares our results with relevant other estimates of the CER supply potential. To allow a meaningful comparison, we include here only estimates of the CER supply potential and do not provide estimates on the likely level of the actual issuance expected under current market conditions, in the absence of new demand. We also only include estimates for the portfolio of all registered projects. Most studies estimate the CER supply potential for a different time period. Considering differences in time period, Cames (2015), UNFCCC (2017a) and World Bank et al. (2016) all arrive at higher estimates. They all do not consider several aspects that could limit the ability to issue CERs, in particular the implementation and operation status of projects and how CDM requirements for renewal of the crediting period can limit the ability to issue CERs. Warnecke, Day, & Tewari (2015) use the same survey data to reflect the status and operation of projects. The value in Table 5 is lower, because Warnecke, Day, & Tewari (2015) consider only the project types covered by the survey and not all years of the period 2013 to 2020. If their results are extrapolated to the full period and all project types, the overall CER supply potential is similar (~4.7 billion CERs). Both studies use the same survey data, but differ in several other aspects, which level each other out. For example, the non-consideration of methodological effects due to the renewal of crediting periods leads to higher estimates in Warnecke, Day, & Tewari (2015) while this study considers a larger number of registered projects due to the increase in the CDM project portfolio between September 2015 and April 2017.

Table 4: Comparison of CER supply potential estimates

Study	CER supply potential (billion CERs)	Notes
Warnecke, Day, & Tewari (2015)	2.9	<ul style="list-style-type: none"> ▶ For the period 2014 to 2020 ▶ Consideration of survey data on the status of projects ▶ Only project types covered by the survey population (71 % of total)
Cames (2015)	≈3	<ul style="list-style-type: none"> ▶ For the period 2017 to 2020 ▶ Based on ex-ante estimates in PDDs, adjusted for issuance success rate ▶ Only projects, no PoAs
UNFCCC (2017a)	7.6	<ul style="list-style-type: none"> ▶ For the period from 2000 to 2020 ▶ Based on ex-ante PDD estimates ▶ Excluding non-approved crediting periods
World Bank et al. (2016)	3.5	<ul style="list-style-type: none"> ▶ For the period 2016 to 2020

3.2 Vulnerability of Discontinuing GHG Abatement

Table 5 and Figure 3 show the total CER supply potential differentiated by project type and vulnerability of discontinuing GHG abatement. Overall, the results show that the vast majority of the CER supply potential in the current situation comes from projects that are likely to continue GHG abatement:

- ▶ **About 82 % of the potential CER supply is estimated to come from project types that are generally likely to continue GHG abatement even without CER revenues.** Many of these CDM projects appear „dormant“ – they do not issue CERs under current market conditions. However, they could any time start issuing CERs retroactively, for emission reductions that occurred in the past years.
- ▶ **By contrast, only 4 % of the potential CER supply is estimated to come from project types that are deemed to be generally vulnerable of discontinuing GHG abatement but can still issue CERs.**
- ▶ **For 13 % of the CER supply, the vulnerability of discontinuing GHG abatement is strongly variable,** depending on the specific circumstances of the project, and for 2 % the vulnerability was not assessed.

That a project is not deemed vulnerable of discontinuing GHG abatement in the present situation, does not contest the assessment of *additionality* at project inception but rather only assess the vulnerability in the current situation.

Table 5: CER supply potential for the period 2013 to 2020

	Billion CERs	%
Total CER supply potential	4.65	100 %
of which already issued CERs	0.34	7 %
Vulnerability of discontinuing abatement		
Low	3.80	82 %
Variable	0.60	13 %
High	0.17	4 %
Not assessed	0.08	2 %
Project types		
Renewable energy	3.16	68 %
Industrial gases	0.37	8 %
Energy efficiency	0.45	10 %

	Billion CERs	%
Fossil fuels	0.41	9 %
Others	0.26	6 %
Regions		
Asia and Pacific	3.83	82 %
Latin America and the Caribbean	0.54	12 %
Africa	0.24	5 %
Economies in transition	0.04	1 %
Programmes of activities (PoAs)		
	0.15	3 %

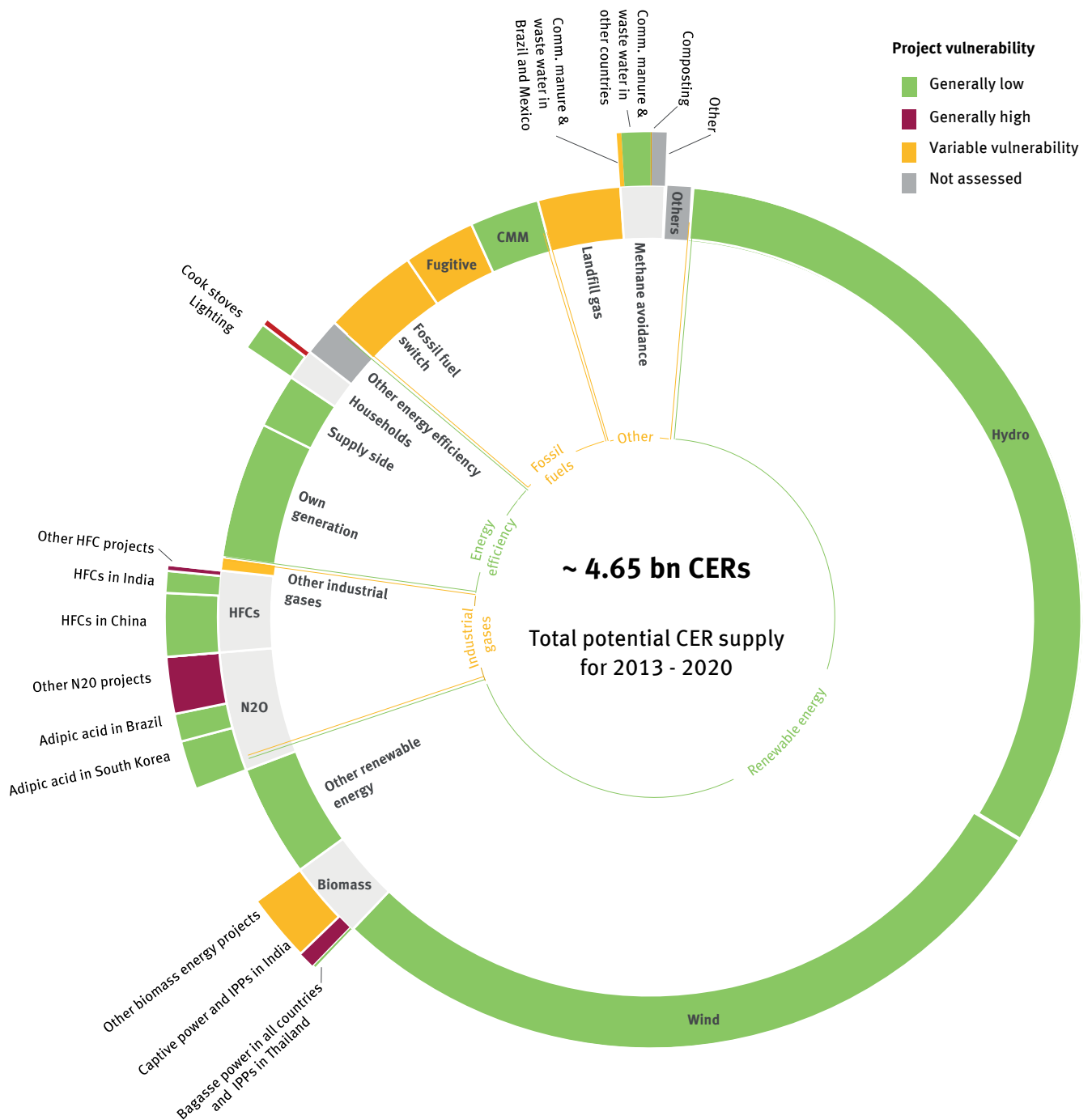


Figure 3: CER supply potential for the period 2013 to 2020 by major project types and vulnerability of discontinuing GHG abatement

The share of CERs from vulnerable project types is not only deemed to be small because of the market share of vulnerable project types, but also for several other reasons:

- ▶ First, many vulnerable projects have already discontinued GHG abatement or stopped monitoring emission reductions, due to their vulnerability. If all registered CDM projects would have been implemented, continued GHG abatement and monitored emission reductions, the share of CERs from vulnerable project types would be twice as high and amount to more than 8 %. The relatively low share of vulnerable projects is thus also a result of the collapse of the market.
- ▶ Second, some baseline and monitoring methodologies for vulnerable project types introduced conservative approaches to determine baseline emissions, in order to address concerns over perverse incentives to inflate the baseline. This holds in particular for HFC-23 and nitric acid projects. Schneider & Cames (2014) estimate that the emission reductions from industrial gas projects over the period 2013 to 2020 would be about 1.7 times higher than the amount of CERs that can be issued. This means that share of emission reductions from vulnerable project types is larger than the share of CERs.
- ▶ Third, some projects that could in principle have a high vulnerability of discontinuing GHG abatement are no longer vulnerable due to domestic policies that incentivize continued abatement. For example, many countries have introduced legislation to support the use of efficient lighting (Warnecke et al., 2017). China and India have introduced domestic policies to address HFC-23 emissions (UNEP, 2017). We assume that these policies effectively address HFC-23 emissions from HCFC-22 plants in these countries and therefore deem HFC-23 projects in China and India to have a low vulnerability. HFC-23 projects in China and India make up 3 % of the CER supply potential.

Another important finding is that the CER supply potential and the project vulnerability differ considerably between project types (see Table 5 and Figure 3):

- ▶ **Renewable energy projects** constitute the project type with the largest CER issuance potential: about two thirds of the overall CER supply for the period 2013 to 2020 could be generated from renewable energy:
 - ▶ **Hydro and wind power projects** contribute most to this potential, making up 57 % of all registered projects and 61 % of the overall CER supply potential. They are assessed to have a low vulnerability of discontinuing GHG abatement. A very large proportion of hydro and wind projects are reported to have been implemented and continue GHG abatement (see Table 1 in section 2.1). Importantly, even if these projects do not issue CERs, data to verify emission reductions ex-post is typically available. Most hydro and wind power projects could thus retroactively issue CERs, as long as CDM requirements for the renewal of crediting periods do not limit their ability to issue CERs.
 - ▶ By contrast, the CER supply potential from **biomass projects** is significantly lower. The vulnerability of biomass projects varies, often depending on the specific circumstances of the project (see Table 2 in section 2.2). This is confirmed by the significant fraction of biomass projects that are reported to have stopped GHG abatement (see Table 1 in section 2.1). Moreover, biomass projects may not always have the necessary data to verify emission reductions. Altogether, these factors limit the CER supply potential from this project types.
- ▶ The relative contribution of **industrial gas projects** in the period 2013 to 2020 is significantly lower than in the first commitment period of the Kyoto Protocol: industrial gas projects make up 52 % the CERs issued for the first commitment period, but are estimated to contribute to only 8 % of the CER supply potential in the second commitment period. This has several reasons: first, many other CDM projects were registered towards the end of the first commitment period. Second, as highlighted above, methodology revisions have considerably lowered the number of CERs these projects can claim. Third, a relatively large number of projects have discontinued GHG abatement or do no longer monitor emission reductions (see Table 1 in section 2.1). A significant share of industrial gas projects are considered to be vulnerable of discontinuing GHG abatement, but conditions vary between countries (see Table 2 in section 2.2).
- ▶ **Energy efficiency projects** account for 10 % of the overall CER supply potential. This includes mostly own generation or supply side projects, such as waste heat recovery. Energy efficiency household projects, such as efficient cook stove or lighting projects, account for only about 1 % of the overall CER supply potential. Most energy efficiency projects are not considered vulnerable of discontinuing GHG abatement, with the exception of cook stove projects (see Table 2 in section 2.2).

- ▶ **Fossil fuel switch projects** also account for 9 % of the overall CER supply potential. This includes the construction of natural gas plants, switch from oil to gas, coal mine methane projects, the recovery of associated gas in the oil industry, and leak detection and repair in natural gas pipelines. The share of projects that continue GHG abatement varies, depending on the project type. Most fossil fuel project types are not considered vulnerable of discontinuing GHG abatement (see Table 2 in section 2.2).
- ▶ **Other projects** include mainly landfill gas and methane avoidance projects and account for 6 % of the overall CER supply potential. The share of these project types is relatively low because a relatively high share of the registered projects has never been implemented and because a relatively high share of these projects has discontinued GHG abatement. For example, nearly two thirds of the landfill gas flaring projects are reported to have stopped GHG abatement (see Table 1 in section 2.1). Many of these project types are indeed assessed to be vulnerable of discontinuing GHG abatement (see Table 2 in section 2.2)

3.3 CER Supply by Region and from PoAs

The regional distribution of the potential CER supply is dominated by the Asia and Pacific region, which accounts for 82 % of the CER supply potential (see Table 5). 60 % of the total CER supply potential comes from China alone, which is similar to its share of 59 % of the CERs issued in the first commitment period. Latin America and the Caribbean account for 12 %, Africa for 5 % and economies in transition for 1 % of the potential CER supply. Though still small, the share of Africa is slightly larger than in the first commitment period of the Kyoto Protocol, in which only 2 % of the issued CERs are from Africa. Africa also hosts a larger share of project types that are deemed vulnerable of discontinuing abatement, compared to other regions: 25 % of the CER supply potential from Africa comes from project types deemed to be highly vulnerable, whereas this share is only 3 % for the other regions. This is due to a relatively high share of cook stove and nitric acid projects in Africa.

The CER supply potential from already included CPAs is about 155 million CERs or 3 % of the overall potential rather small (see Table 5). In this paper, the CER supply potential from PoAs only considers CPAs that were included as of 12 April 2017. However, registered PoAs can include an unlimited number of CPAs in a programme. The actual CER supply potential from registered PoAs could thus be larger, depending on how many CPAs would be included. PoAs include a higher share of project types that are vulnerable of discontinuing abatement: 29 % of the CERs from PoAs are assessed to come from projects that are deemed vulnerable, whereas this share is only 4 % for CDM project activities.

4 Conclusions

This discussion paper investigated how many CERs from already registered projects could be issued for emission reductions up to 2020, taking into account the most recent knowledge on the status and operation of CDM projects and CDM regulatory requirements, and the extent to which these CERs would come from projects that are vulnerable of discontinuing GHG abatement. The paper finds that the total CER supply potential is with 4.7 billion CERs considerable, exceeding by far current levels of issuance and demand. However, the vast majority of CERs come from projects that are likely to continue GHG abatement, even without new demand for CERs, also because a significant share of vulnerable projects already stopped their activities.

These findings have important implications for policy makers deliberating on programmes or policies that purchase or recognise CERs. First, the findings could help assess whether demand created by such programmes or policies could be met with sufficient supply. Second, our analysis could help assess the GHG emissions implications from establishing programs or policy that create new demand for CERs.

The current market situation is characterized by a strong imbalance between supply and demand. In this situation, creating new demand for CERs does not necessarily trigger further emission reductions, since most registered CDM projects continue GHG abatement, whether or not they issue and sell CERs. Creating new demand for CERs would only trigger further emission reductions to the extent that (a) projects that are vulnerable of discontinuing GHG abatement are enabled to continue GHG abatement, that (b) the implementation of new projects is triggered through the programme or policy, or that (c) the overall demand from all programs and policies would exceed the potential CER supply from registered projects.

To ensure a high GHG mitigation impact, policy makers could therefore consider prioritizing the purchase or recognition of CERs either from new projects implemented after the adoption of the policy or program, or from projects considered vulnerable of discontinuing GHG abatement. Indeed, some purchase programs have focused on vulnerable project types, including the Norwegian purchase programme, the World Bank's Pilot Auction Facility for Methane and Climate Change Mitigation and a German initiative to address N₂O emissions from nitric acid production.

Several aspects are worth noting. First, as highlighted above, the fact that a project is not deemed vulnerable of discontinuing GHG abatement does not contest the assessment of additionality at project inception. Rather, it recognises that, from a today's perspective, the project's savings or revenues from continued operation exceed its operational expenditures.

A further consideration is the question whether the purchase of CERs from registered projects would restore trust in the CDM market. Many CDM projects were developed with the expectation of future CER revenues. The collapse of CER prices came for many project developers unexpectedly. One could thus argue that it might restore trust if project owners could still sell their CERs. On the other hand, one could argue that trust in the market was already lost and revenues from CERs were written off. It is thus uncertain whether rewarding project developers today, years after the market collapse, would restore trust in a future market.

Another important aspect are the incentives for project developers. Rewarding existing projects does not necessarily create incentives for developing new projects. Already implemented projects that continue GHG abatement typically have lower marginal costs for issuing CERs than new or vulnerable projects. Our analysis suggests that about 3.80 billion CERs could come from registered projects that are not vulnerable of discontinuing GHG abatement. Many of these projects have relatively low costs for monitoring and verifying emission reductions, in particular hydro and wind power projects which together account for 2.82 billion CERs. By contrast, new projects and registered projects that are vulnerable of discontinuing GHG abatement may have higher costs of generating CERs. If CERs from all registered and new projects were eligible under new demand sources, there is a possibility that registered non-vulnerable projects would outcompete new or vulnerable projects. In this situation, registered non-vulnerable projects might serve most of the demand.

We recommend further investigating the economic implications of using CERs under new programmes or policies. Information on marginal costs for continuing GHG abatement, monitoring and verifying emission reductions and issuing CERs for different project types could help to understand the economic implications, in particular on the actual supply and CER prices in response to such new demand. It may also allow better understanding of how different demand sources with different eligibility requirements for CERs impact the supply and prices of different market segments.

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Annex: Further Information on Data Sources and Assumptions

This Annex provides further information on the data sources and assumptions, including which data is used to assess each of the questions in Figure 1 in section 2.1.

A1: Technical Implementation and Operation Status of Projects

In this section, we describe in more detail how we assess the implementation status of projects (questions 1, 2, 6 and 9 in Figure 1). The impact of delays in implementing projects is discussed in section A4 below.

Initial implementation of projects

The initial implementation of a project is an obvious prerequisite for issuing CERs. We use two steps to assess whether a project has ever been implemented (question 1 in Figure 1):

- ▶ We first evaluate for each project *individually* whether it has ever issued CERs, using data from UNFCCC (2017b). If a project has ever issued CERs, it has been implemented. For projects with CER issuance we thus assign a 100 % likelihood that the project has ever been implemented. As of 12 April 2017, 38 % of the registered projects have issued CERs.
- ▶ For the remainder of the projects, we assess the probability of implementation for each project *category*. We use the survey responses to question 3 in Warnecke, Day, & Klein (2015) – „What is the technical implementation status of the CDM GHG mitigation activity now?“ – to assess the probability of implementation for each project category in Table 1 in section 2.1. We evaluate the survey responses as follows: we assume that a project has ever been implemented if its 2014 status was that (a) implementation or construction had been started, that (b) the investment decision had been made, or that (c) the project had initially been implemented but later been dismantled. However, we assume that projects which reported to be in a planning phase in 2014, have not been implemented, as their future implementation is more uncertain. Table 1 in section 2.1 shows for each project category the share of projects that are deemed to have ever been implemented, which is used here as the probability of implementation for the respective category. However, the survey results apply to all projects, including those that have issued CERs. We therefore calculate an adjusted probability of implementation, applicable only to those projects that have not yet issued CERs, such that the probability of implementation of all projects in a category, including those that have issued CERs, matches the results of the survey.

Continued abatement of projects

Abatement of GHG emissions is another prerequisite for issuing CERs. We use two steps to assess whether a project has continued and can continue GHG abatement (question 2 in Figure 1):

- ▶ We assume that projects have continued GHG abatement if they have recently issued CERs (i.e. in 2016 or 2017). We use data from UNFCCC (2017b) to assess for each project *individually* whether it has issued CERs recently. As of 12 April 2017, 7 % of the registered projects have issued CERs in 2016 or 2017.
- ▶ For the remainder of the projects, we assess the probability of continued abatement for each project *category*. We use the survey responses to question 5 in Warnecke, Day, & Klein (2015) – „What is the operational status of the CDM component of the GHG mitigation activity, now?“ – to assess the probability of continued abatement for each project category in Table 1 in section 2.1. We evaluate the survey responses as follows: we assume that a project continues abatement if its 2014 status was that it was (a) in „regular operation“ or (b) in „non-CDM conformant operation, alternative GHG mitigation equipment operating“. We only include projects in the analysis that have earlier responded in the survey that they have ever been implemented. Table 1 in section 2.1 shows for each project category the share of projects that are deemed to continue GHG abatement, which is used here as the probability of implementation for the respective category. However, the survey results apply to all projects, including those that have recently issued CERs. We therefore calculate an adjusted probability of continued abatement, applicable only to those projects that have not issued CERs recently, such that the probability of continued abatement of *all* projects in a category, including those that have issued CERs recently, matches the results of the survey.

In applying this approach, we make two important assumptions: first, we assume that projects which are deemed to have discontinued GHG abatement have done so immediately after the last day for which CERs were issued. Second, we assume that projects that are deemed to continue GHG abatement based on the survey results from 2014, have also continued GHG abatement thereafter. The first assumption could lead to an under-estimation of the CER supply potential, the second to an over-estimation.

Ability of projects to resume abatement with appropriate incentives

To assess whether discontinued projects could resume abatement (question 6 in Figure 1), we use information from the survey conducted by Warnecke, Day, & Klein (2015). In the survey, discontinued projects indicated whether they were temporarily or permanently discontinued. This information is used to assess the ability of projects to resume abatement: the proportion of projects that are understood from the survey to be dismantled but only “temporarily stopped”, as a proportion of all stopped projects (technically dismantled, or technically implemented but permanently or temporarily stopped), is assumed to equate to the proportion of discontinued projects that may be able to resume abatement. Here, the assumption is taken that the type of discontinuation status is sensitive to the incentives for abatement: it is assumed that projects where respondents indicated permanent closure and/or technical dismantling would not be sensitive to changes in the available incentives, whilst those indicating temporary discontinuation would be sensitive to such changes. This is a simplified assumption since other factors may have influenced the choice of discontinuation status selected by respondents, but this is not considered likely to shift the result in any particular direction.

For project type categories where the number of responses in the survey from discontinued projects was high enough to indicate a trend (minimum of 5 projects), the probability that these projects could resume abatement is taken from the survey results of these specific project types. For project type categories where the number of responses from applicable projects was not high enough to derive a meaningful trend, the overall proportion from the CDM population – including all of the project types assessed in the survey – was applied.⁷

Ability to implement projects with appropriate incentives

If projects have not been implemented so far, it does not necessarily mean that they can never issue CERs. Some projects may have faced delays or may not have been implemented due to the current market situation, but could still be implemented at a future point in time. Other projects may not be able to proceed to implementation any longer, for example, if they were not technically feasible or did not get the necessary permits.

We could not identify information to assess how many of the non-implemented projects could still be implemented. In the absence of further information, we assume for question 9 in Figure 1 above that 50 % of the non-implemented projects could still be implemented at a future point in time. It is important to note that this assumption does not significantly impact the overall CER supply potential, due to the low number of non-implemented projects. The CER supply potential would be 0.3 % larger or smaller if we would assume that all or none of the projects could still be implemented, respectively.

A2: Crediting Periods and Emission Reduction Calculations

Under the CDM, project participants can choose between a fixed crediting period of 10 years or a renewable crediting period of seven years which can be renewed twice. A PoA has a duration of up to 28 years and has to be renewed every four years. Each CPA has an individual crediting period which is, as for projects, either a fixed 10-year crediting period or a renewable crediting period of 7 years which can be renewed twice. For AR projects, the fixed crediting period is 30 years, the renewable crediting period is 20 years, and their maximum total duration is 60 years. For years where a crediting period starts or ends, we determine the fraction of emission reductions that occur in the relevant time period.

In principle, CERs can be generated for emission reductions occurring from the start of the first crediting period until the end of the last crediting period. However, projects that have chosen a renewable crediting period type have to request for renewal before the previous crediting period expires in order to continue issuing CERs.

⁷ Due to sufficient responses at the level of the UNEP DTU project type, the value for the UNEP DTU project type was applied for some of the more refined project categories included in Table 1 in section 2.1. This is the case for palm oil solid wastes (biomass energy) and domestic manure (methane avoidance). For two project subtypes (solar water heating and composting) only four responses were received by projects in a state of discontinuation relevant to this question, nevertheless, the trend from these four responses is used as the authors consider that it represents a fair number of the total potential projects from these categories in this situation.

Getting approval for a renewal of a crediting period is typically not difficult; importantly, neither the additionality nor the baseline scenario must be re-assessed at the renewal, even if the activity has become common practice in the host country.⁸ As of 12 April 2017, 355 requests for renewal of second or third crediting periods have been approved, while none of the requests has been rejected by the CDM Executive Board. We therefore assume that all projects and CPAs could renew their crediting period if they wish to do so.

However, delays in the renewal of a crediting period can impact the ability of project participants to issue CERs. Project participants wishing to renew the crediting period of their project have to notify the UNFCCC secretariat by 180 days before the previous crediting period expires. If this notification is not received in time and the crediting period is not renewed, the project participants are not entitled to claim any CERs for a defined period, namely from the end of the previous crediting period until the crediting period is renewed or for the duration that the notification was delayed, whichever is earlier.⁹ Whether a notification has been submitted, has therefore important consequences for the project's ability to issue CERs:

- ▶ **Projects with notification:** Projects that have submitted the notification in time could retroactively renew their crediting period and issue CERs, even if the last crediting period ended a long time ago.
- ▶ **Projects without notification:** Projects that have not submitted the notification could still renew their crediting period but could only issue CERs for future years, once the crediting period renewal has been approved.

To assess whether projects have taken the necessary administrative steps to renew their crediting period (question 5 in Figure 1), we use information on the status of renewal and the submission of notifications in the UNFCCC database (UNFCCC, 2017b).¹⁰ Among the 1485 projects for which a renewal was due in the period up to mid 2017, only 355 projects have either renewed their crediting or submitted a notification for renewal, whereas the other 1130 projects have not done so.

The renewal of crediting periods can also impact the methodological approaches used to calculate emission reductions, as included in baseline and monitoring methodologies, methodological tool and standardized baselines. The methodological approaches to determine emission reductions are usually fixed for a crediting period. At the renewal of the crediting period, the project participants have to update the methodological approaches and data used to calculate emission reductions, using a methodology version that is valid at the time of renewal. For example, renewable power generation projects have to update the grid emission factor they use. In some instances, methodological approaches to calculate emission reductions have been revised substantially over time, altering the amount of emission reductions that projects can claim. Methodological changes affecting the calculation of emission reductions are most significant for industrial gas projects, in particular abatement of N₂O from adipic and nitric acid production and abatement of HFC-23 from HCFC-22 production. For these project types, we use detailed bottom-up estimates of the emission reduction volume which reflect the methodological changes applicable at the renewal of the crediting period (Schneider and Cames 2014). For other projects, we use the ex-ante estimates of emission reductions provided in project design documents (PDDs). We always use the PDD prepared for the relevant crediting period where available. If the crediting period has not yet been renewed, we use information from the PDD of the previous crediting period.

A3: Availability of Data to Monitor Emission Reductions

Monitoring emission reductions is a further prerequisite for issuing CERs. To assess which projects have sufficient data to continuously monitor emission reductions (questions 3 and 4 in Figure 1), we use information on the last CER issuance (UNFCCC, 2017b), draw upon the results of the survey conducted by Warnecke, Day, & Klein (2015), and evaluate methodological requirements for monitoring emission reductions, as follows:

- ▶ We assume that projects have a CDM monitoring system in place and continue to monitor emission reductions, if they have recently issued CERs (i.e. in 2016 or 2017). We use data from UNFCCC (2017b) to assess for each project *individually* whether it has issued CERs recently. As of 12 April 2017, 7 % of the registered projects have issued CERs in 2016 or 2017.
- ▶ For the remainder of the projects, we assess the probability that a CDM monitoring system is in place for each

⁸ Paragraphs 300 to 305 of version 09.0 of the project standard.

⁹ Paragraph 290 of version 09.0 of the project cycle procedure.

¹⁰ Information on the notification for the renewal of the crediting period was included in database version released on 17 January 2017 but is not available anymore in more recent versions of the database. We use the information in the database published on 17 January 2017 to assess the status on notifications. According to this database version, only four projects had submitted a notification but not yet proceeded to the renewal of their crediting period.

project *category*. We use the survey responses to question 9 in Warnecke, Day, & Klein (2015) – „What is the implementation status of the CDM monitoring system (measurements required for the CDM only)?“ – to assess the probability that a CDM monitoring system is in place for each project category in Table 1 in section 2.1. We evaluate the survey responses as follows: we assume that projects have a monitoring system in place if they reported that their CDM monitoring system is „implemented and operational“. We only include projects in the analysis that have earlier responded in the survey that they have been implemented and continue GHG abatement. Table 1 in section 2.1 shows for each project category the share of projects that are deemed to have a CDM monitoring system in place. However, the survey results apply to all projects, including those that have recently issued CERs. We therefore calculate an adjusted probability that a CDM monitoring system is in place, applicable only to those projects that have not issued CERs recently, such that the probability for *all* projects in a category, including those that have issued CERs recently, matches the results of the survey.

- ▶ If projects do not have a full CDM monitoring system in place, it does not necessarily mean that they cannot issue CERs. Generally, monitoring of emission reductions has to occur in accordance with a registered monitoring plan and should be continuous – meaning that it should be conducted from the start of operation of the project throughout the crediting periods, without interruptions. However, the current CDM requirements provide for flexibility to accommodate lacking monitoring data through requests for temporary deviations from or permanent changes to the registered monitoring plan. Project participants can request for temporary deviations from the registered monitoring plan if they were unable to monitor the registered CDM project activity in accordance with the monitoring plan. They can propose alternative monitoring arrangements, applying conservative assumptions or discount factors when calculating emission reductions. Project participants can also request for approval of permanent changes to the registered monitoring plan, including alternative approaches to monitor emission reductions. Importantly, such requests can be made ex-post, together with a request for issuance, even years after the changes occurred. Altogether, these provisions provide considerable flexibility to project participants in monitoring emission reductions. For projects that did not have a full CDM monitoring system in place in recent years, a key question is thus whether they still have sufficient data to report verifiable emission reductions. This depends largely on the monitoring requirements of the relevant baseline and monitoring methodologies. For some project types, key monitoring data, such as the amount of renewable electricity generated, is usually available, even if the CDM was no longer considered. For other project types, key monitoring data, such as surveys on the continued use of cook stoves, could be lacking if monitoring for CDM purposes was interrupted. In Table 6, we briefly evaluate the monitoring requirements in key CDM methodologies to assess for all project types whether they are likely to have all key data to report verifiable emission reductions. Noting the enhanced flexibility for temporary deviations from and permanent changes to monitoring after registration, we assume that project types, which are deemed to generally have the necessary data in Table 6, can report verifiable emission reductions, regardless of whether they maintained a full CDM monitoring system.

Table 6: Availability of key monitoring data in the absence of a full CDM monitoring system

Project type	Is key monitoring data likely to be available?	Remarks
Afforestation / Reforestation	Yes	Carbon stocks can be quantified any time, continuous monitoring is not necessary
Agriculture	Yes	This category includes mostly fossil fuel switch and energy efficiency measures (see rationale for these categories)
Biomass energy	No	Key parameters may not be collected, such as the amount of properties of the biomass used or regular surveys to assess the availability of biomass
Cement	Yes	This category includes mostly projects increasing the blending rate of cement. Data on the cement composition is typically available
CO ₂ usage	Yes	The amount of gas recovered in facilities is typically available
Coal bed/mine methane	No	The amount of methane captured may not be measured
Energy distribution / EE industry / EE own generation / EE service / EE supply side	Yes	Energy flows are typically known
EE households	No	Household surveys on the continued operation of equipment may not be carried out
Fossil fuel switch	Yes	Fossil fuel use is typically measured
Fugitive	No	Measurements of gas leaks may not be conducted
Geothermal, Hybrid renewables, Hydro, Mixed renewables, Tidal, Solar, Wind	Yes	Power generation data is commonly collected Grid emission factors can usually be calculated ex-post based on statistics
HFCs	No	Measurements of the amount of HFC-23 generated and destroyed may not be conducted
Landfill gas	No	Measurements of the amount and methane content of landfill gas captured may not be conducted
Methane avoidance	No	The amount of activities conducted (manure used, waste composted) may not be available
N ₂ O	No	Measurements of N ₂ O in the tail gas of the plants may not be conducted
PFCs and SF ₆	No	For most project types, particular measurements are necessary (e.g. amount of SF ₆ recovered) which may not be conducted
Transportation	No	Passenger surveys about distance travelled and the mode of transportation in the baseline may not be carried out

In applying this approach, we make two important assumptions, consistent with previous assumptions: first, we assume that projects which are deemed not to have a CDM monitoring system in place have abandoned monitoring immediately after the last day for which CERs were issued. Second, we assume that projects that are deemed to have a CDM monitoring system in place based on the survey results from 2014, have also continued monitoring thereafter. The first assumption could lead to an under-estimation of the CER supply potential, the second to an over-estimation.

A4: Project performance, delays in project implementation, differences between ex-ante and ex-post emission reduction calculations, adjustments in monitoring emission reductions

When registering a project or renewing a crediting period, project participants have to provide an ex-ante estimation of the emission reductions throughout the applicable crediting period in the PDD. The actual amount of emission reduction claimed ex-post when requesting issuance of CERs can be lower or higher than the ex-ante estimates anticipated when preparing the PDD, for several reasons:

- 1. Project performance:** Projects may operate differently than anticipated in the PDD. For example, the amount of wind power generated depends on the wind availability and the technical performance of the plant, which could differ from assumptions made in PDDs.
- 2. Delays in implementation:** If projects are brought to operation at a later stage, this could reduce the amount of CERs that can be claimed (if the start of the crediting period is not changed).
- 3. Monitoring performance:** Some projects can face data gaps or data quality issues. These issues can be addressed by requesting for temporary deviations or permanent changes to the monitoring plan, but often require more conservative approaches to be applied in calculating emission reductions. This can reduce the amount of CERs claimed compared to assumptions made in PDDs.
- 4. Differences in methodological approaches to calculate ex-ante emission reductions:** Some methodologies prescribe specific methods for the calculation of ex-ante emission reductions, which differ from how emission reductions are quantified ex-post. For example, landfill gas methodologies require application of a first order decay model to predict methane generation from landfills, whereas the actual amount of gas captured is used to quantify emission reductions ex-post.

The actual amount of CERs issued in relation to the amount anticipated in PDDs is also referred to as „issuance success rate“ (UNEP DTU, 2017). The issuance success rate captures all four reasons for possible differences between ex-ante estimates and actual CERs issued. It differs strongly between project types: most industrial gas projects have generated more CERs than anticipated in PDDs. By contrast, landfill gas projects, for example, on average issued only 56 % of the amount of CERs calculated ex-ante in PDDs (UNFCCC, 2017b). We therefore reflect in our analysis these differences between project types, as follows:

- ▶ For industrial gas projects, we use the detailed project-specific estimates of the emission reduction volume developed by Schneider and Cames (2014). These estimates consider the plant-specific performance, the specific methodological requirements in the relevant methodologies, including changes at the renewal of the crediting period, as well as conservative assumptions in monitoring emission reductions.
- ▶ For all other projects, we estimate the emission reduction volume based on the ex-ante estimation of emission reductions in PDDs, adjusted for the issuance success rate for the relevant project category. We derive the issuance success rate from the UNFCCC database (UNFCCC, 2017b).

A5: Data gaps

The survey by Warnecke, Day, & Klein (2015) covers the most important project types: 82 % of the projects registered as of 12 April 2017 belong to a project type covered by the survey. For project types not covered by the survey, we use the survey results from either the global average of all surveyed projects, or the results from similar project types: We use the global average values for the following UNEP DTU project types not covered by the survey: afforestation, agriculture, CO₂ usage, energy distribution, fugitive, HFCs (other than HFC-23), landfill gas (other than flaring or power generation), PFCs and SF₆, reforestation, and transport. We use the average from all renewables for the following project types: geothermal, hybrid renewables, mixed renewables, and tidal. For EE service and EE supply side, we use the average of EE industry and EE own generation. For hydro power plants above 20 MW we use value for hydro power plants between 2-20 MW. For N₂O projects other than nitric or adipic acid, we use the values for nitric acid projects. For all other projects, we use the average values from all project types in Table 1 that belong to the same UNEP DTU classification. For example, for EE household projects other than stoves or lighting, we use the aggregated values from stoves and lighting.

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