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Volumes and types of unused Certified Emission Reductions (CERs)

Lessons learned from CDM transactions under the Kyoto Protocol, transparency gaps and implications for post-2020 international carbon markets

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Abbreviations

A6.4ER	Article 6.4 Emission Reduction Credit
A6.4M	Article 6.4 Mechanism
AA	Assigned Amount
AAU	Assigned Amount Unit
AC	Administrative Cancellation
AF	Adaptation Fund
AGN	African Group of Negotiators
AILAC	Independent Alliance of Latin American and Caribbean States
AOSIS	Alliance of Small Island States
Bn	Billion
BTR	Biennial Transparency Report
CARP	Centralized Accounting and Recording Platform
CCER	Chinese CER
CDM	Clean Development Mechanism
CDM EB	CDM Executive Board
CDMR	CDM Registry
CER	Certified Emission Reduction
CiDEV	Carbon Initiative for Development
CMA	COP Serving as The Meeting of The Parties to The Paris Agreement
CMP	COP Serving as The Meeting of The Parties to The Kyoto Protocol
CO_2	Carbon Dioxide
COP	Conference of the Parties
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CP	Commitment Period

DNA	Designated National Authority
DOE	Designated Operational Entity
EE	Energy Efficiency
EIT	Economies in Transition
ERUs	Emission Reduction Units
ETF	Enhanced Transparency Framework
ETS	Emission Trading System
EU	European Union
EU ETS	EU Emissions Trading System
EUA	EU Allowances
EUTL	EU Transaction Log
GHG	Greenhouse Gas
HCFC-22	Chlorodifluoromethane
HFCs	Hydrofluorocarbons
IET	International Emission Trading
IGES	Institute for Global Environmental Strategies
IPCC	Intergovernmental Panel on Climate Change
ITL	International Transaction Log
ITMO	Internationally Transferred Mitigation Outcome
JCM	Joint Crediting Mechanism
JI	Joint Implementation
JISC	JI Supervisory Committee
KCU	Korean Credit Unit
KETS	Korean ETS
KP	Kyoto Protocol
lCER	Long-Term CER
LDC	Least Developed Country
LFG	Landfill Gas
LULUCF	Land-Use, Land-Use Change and Forestry
MPG	Modalities, Procedures and Guidelines
$MtCO_2e$	Metric Tonnes of CO_2 equivalent
N_2O	Nitrous Oxide
NACAG	Nitric Acid Climate Action Group
NC	National Communication
NDC	Nationally Determined Contribution
NGO	Non-governmental Organizations
NIR	National Inventory Report
NR	National registry
PA	Paris Agreement
PAF	Pilot Auction Facility
PoA	Programme of Activities

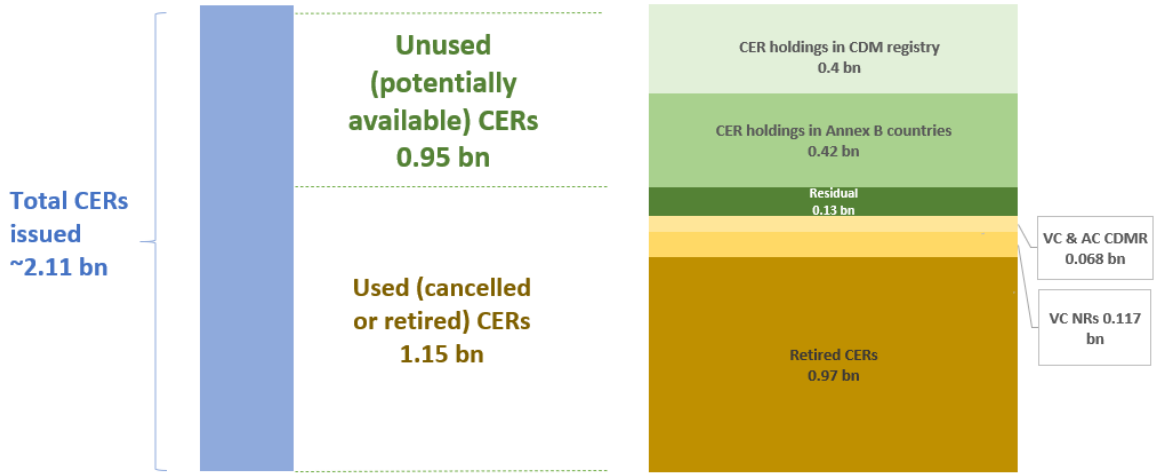
QELRO	Quantified Emission Limitation and Reduction Objective
RMP	Rules, Modalities and Procedures
RMU	Removal Unit
SB	Supervisory Body
SBI	Subsidiary Body for Implementation
SEF	Standard Electric Format
SOP	Share Of Proceeds
STL	Supplementary Transaction Log
tCER	Temporary CER
TER	Technical Expert Review
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
VC	Voluntary Cancellation

Executive Summary

The transition of the Clean Development Mechanism (CDM) of the Kyoto Protocol (KP) into the Article 6.4 mechanism of the Paris Agreement (PA) is highly contentious in the negotiations in the run-up to COP26, particularly regarding the transition of Certified Emission Reductions (CERs). Various proposals for limiting CER transition have been made, for example by introducing cut-off thresholds for the registration date of eligible projects as well as project type-specific eligibility. The negotiations suffer from the absence of robust analysis on the volume of 'unused' CERs that could request transition as well as their characteristics regarding host countries and project types, differentiated by registration dates.

Based on a dataset compiled by Betz et al. (2021), we present a novel analysis of unused CERs as of the end of 2020 according to these criteria, combining a 'top down' analysis of data through 'backward induction' from reports of countries and the CDM registry to the UNFCCC with a 'bottom-up' analysis of national registries of Annex B countries. Estimating the number of unused CERs is challenging as a combination of different sources with different cut-of dates as well as details of is available, reflecting that the process of standardizing transparency under the Kyoto regime is not sufficient. There are highly different national approaches to publication and sharing of data, with dates for disaggregated registry information varying from 2018 (EU and Switzerland) to 2021 (Japan).

Figure 1: Overview of total CERs issued, unused and used CERs (in billion)



Source: authors, based on based on Betz et al. (2021). Note: VC: Voluntary cancellation; AC: administrative cancellation; NR: national registries; CDMR: CDM registry. The volume of unused CERs can be estimated with different methods. The figure presented corresponds to a 'backward induction approach' described in more detail in chapter 3.1.2.

The CER price crash after 2011 has led to the accumulation of significant CER volumes by project developers and other stakeholders in various places, including the CDM registry and registries of Annex B countries. A highly problematic issue is the accumulation of 'zombie' CERs that should have been cancelled as per the rules of the KP, due to the open-ended rules on carry-overs between the 1st and 2nd Commitment Period under the KP, which amount to 36 million units. We estimate a total volume of

about 895 million unused CERs through the backward induction estimate (top down) and 955 million through the backward induction (bottom-up), both higher than the officially reported sum of 822 million CERs (assumed to be due to the missing data on voluntary cancellations). About 400 million of these lie in the CDM registry. Two thirds of the unused CERs come from projects registered in the period 2008-2012, making a 2013 cut-off date relatively stricter than a 2008 date. A 2016 cut-off date would reduce CERs available for transition to less than 10 million.

We find that different registration cut-off dates have very different impacts on CER transition according to project types and host countries. Large projects would be disproportionately impacted from early cut-off dates. With regard to project types, HFC projects have been able to sell the bulk of their CERs, followed by N_2O projects, and thus would suffer less from an exclusion. For all other project types, the share of unused CERs remains above 50% and they would thus be eager to benefit from a transition. Compared to an earlier OECD analysis, we find a smaller exposure for China and India, but a larger exposure for Brazil and Indonesia. The large players China, India and Brazil would suffer strongly from a late cut-off, with Brazil and India losing most from a 2008 cut-off, while China would lose particularly from a 2013 cut-off. Africa would benefit from a 2016 cut-off as it has increased its share in global CER issuance strongly but to date sold only a very small share of the recent CERs; the situation for the second tier of Asian host countries is comparable. Latin American host countries other than Brazil have sold early and only registered few recent projects, and therefore has limited stakes.

The analysis of national registries of Annex B countries shows significant differences in regional distribution of host countries and project types. The former is surprisingly not linked to the geographic vicinity and trade links of countries. The EU and Japanese registry still have significant holdings of CERs from industrial gas projects, which is not the case for Australia and Switzerland.

We hope that our results can inform negotiators under the PA and the KP to better understand impacts on on-the-ground activities when discussing on future uses of CERs that have been accumulated. Some Parties demand that (part of) these unused CERs are made eligible for use towards post-2020 NDC targets, to ensure that investors in the CDM and programme developers can secure a return on their investment. Other Parties are rejecting this due to concerns about environmental integrity due to the risk of (a) reducing post-2020 mitigation efforts as CERs are used to offset emissions that would otherwise be reduced and (b) CERs being used post-2020 while the emissions reductions underlying the CERs have been used to derive the emission scenarios of the NDCs, which leads to intertemporal double counting. Parties to the PA have a broad range of options to allow for a restricted eligibility of CERs in the context of NDCs that can be combined to achieve a compromise acceptable for all Parties (see Table 1 below). Some options (category A) lead to more than half of the unused CERs to be eligible in post-2020 carbon markets, other options (category B) restrict eligibility to a low share of unused CERs, ranging from 3 to 25 million, or not allowing pre-2020 units' use in post-2020 NDCs.

Table 1: Options for eligibility of CERs in post-2020 carbon markets

Category	Option	Conditions
A: broader transition	Option 1	Making all CERs issued but unused to date principally eligible for use in post-2020 carbon markets.
	Option 2	Only excluding certain activity types (here: HFC and N_2O abatement) from eligibility in post-2020 carbon markets.
	Option 3	Restricting eligible CERs to those registered from 2008 onwards, the start of CP1 of the KP.
	Option 4	Restricting eligible CERs to those remaining in the CDM registry.
B: limited transition	Option 5	Restricting eligible CERs to those registered from 2013 onwards, the start of CP2 of the KP.
	Option 6	Restricting use of pre-2020 CERs to a carry-over of 2.5% of CERs from CP2 vintages issued in the host country.
	Option 7	Restricting eligible CERs to those registered from 2016 onwards, corresponding to the early action period under the PA
	Option 8	No eligibility of CERs for use in post-2020 NDCs.

Figure 2: Volumes of unused CERs for different transition options

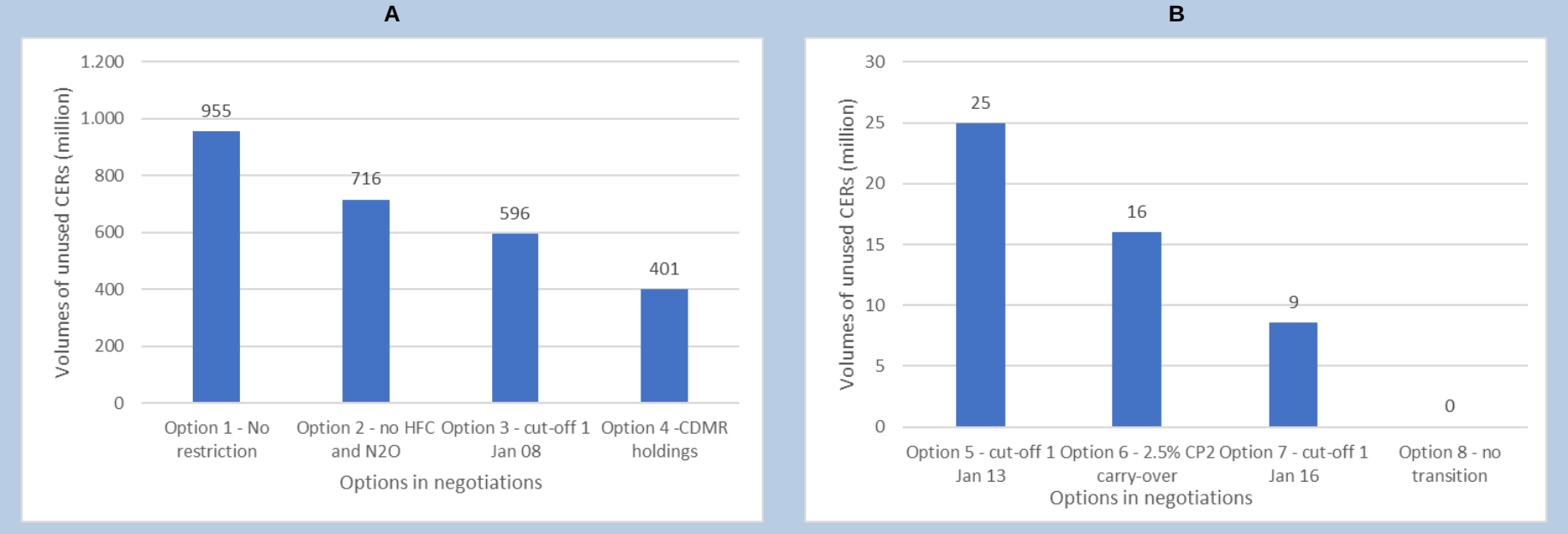


Figure 2.A: “No restriction/Lenient transition options”, Figure 2.B: “No transition/Restrictive transition options”. Source: authors, based on based on Betz et al. (2021). Note: The different characteristics (e.g., project types, origins of CERs) of these volumes are illustrated in more detail in chapter 3. Please note the different scales of the y-axis in both subfigures.

CERs in *national registries* of Annex B Parties that are not made eligible under the PA will have to be mandatorily cancelled at some point after the true-up period of CP2. This rule will not apply to the CERs in the CDM registry, for which Parties to the KP must decide what shall happen with them. Parties can allow the continued use of these CERs for voluntary purposes, non-UNFCCC compliance regimes (e.g., in international civil aviation) or also decide on a mandatory cancellation. Any such mandatory cancellation (be it in national registries or the CDM registry) will result in a de-facto expropriation of the, mostly private, owners of the CERs, which proved to be legally challenging in some Annex B countries.

Regarding A6.4M governance, we recommend that a 'regulatory slippage' towards un-transparent registries needs to be prevented under the PA. In the absence of an International Transaction Log surveilling the transactions among Parties, reporting on transactions, including associated identifiers of units and information on the underlying mitigation action, will be crucial to enhance trust in international carbon markets. Parties must agree on rules that carefully balance the need for transparency and the need to protect confidential information. Aggregation should be allowed to a certain extent, e.g., aggregating all holdings of entities and all holdings of Parties, but underlying and credit-specific information must be disclosed, at the latest after three years. The generation of 'zombie' units should not recur, and to ensure this, rules for mandatory cancellation of units need to be agreed upon also for the PA. We note that such cancellation amounts to expropriation which has proven highly challenging in practice, where carbon credits are owned by the private sector, and not the government. Compensation schemes for expropriated CER owners run through reverse auctions of compensation amounts could at least partially resolve this issue. Parties must be pro-active in negotiations on these challenging issues and avoid the repetition of regulatory uncertainty in future carbon markets.

Ongoing negotiations under the CMA focus on determining potential eligibility of CERs based on registration date cut-offs. However, we want to emphasize that different parameters can be considered. If Parties chose to make some CERs eligible for use in post-2020 NDCs, different options have implications on project types and host countries that may benefit from being able to sell their CERs in post-2020 compliance carbon markets or use them in their own NDCs. A principle-based approach to transition could for instance lead to the exclusion of certain project types that are recognized to no longer be suitable in a PA context. Alternatively, host countries could be put in the driving seat of the transition process through setting quantitative limits of using CP2 CERs activities in the first NDC implementation period. Host countries could then choose within an internationally agreed quantitative limit which project types, project participants or vintages of CERs they want to promote in the context of their NDCs or authorize for international transfer. A quantitative limit consistent with experiences under the Kyoto Protocol would be 2.5% of total CP2 units issued.

1. Introduction

1.1. Context

The upcoming decade from 2021-2030 − the first implementation period of Nationally Determined Contributions (NDCs) for most Parties − is critical for the international community to keep the global long-term goals of the Paris Agreement (PA) (limiting temperature increase to 'well below' 2°C, ideally 1.5°C) within reach. The PA wants to reach global peak greenhouse gas (GHG) emissions as soon as possible and achieve a balance of emissions and sinks in the second half of the century.

International carbon markets can mobilise public and private finance for mitigation. Carbon markets have a long history, starting in 2001 with the agreement on rules for the implementation of the Kyoto Protocol's (KP) three international flexibility instruments. The most prominent of those, the Clean Development Mechanism (CDM) generated more than 8200 registered projects and over 2 billion issued Certified Emission Reductions (CERs). CERs can be used by developed countries for meeting their quantified emission limitation and reduction objectives (QELROs) until the end of the second commitment period (CP2) of the KP in 2020 and its true-up period scheduled around 2023. Beyond the use for QELROs, CERs are used for different purposes, including national baseline and credit schemes and international voluntary carbon markets, or in the context of results-based international climate finance.

With regards to international carbon markets and their use to support NDC attainment, all Parties to the PA must follow the provisions in Article 6 and related future decisions. Article 6.4 of the PA establishes a new crediting mechanism (A6.4M) as a successor to the CDM. Article 6.4 Emission Reduction credits (A6.4ERs) will be traded on international carbon markets according to the Article 6.2 guidance, which foresees the transfers of carbon credits as 'internationally transferred mitigation outcomes' (ITMOs), based on authorization of transfer by the host Party. Moreover, ITMOs need to satisfy specific criteria under the Article 6.2 guidance, including environmental integrity, transparency, and the avoidance of double counting. The Article 6.4 mechanism will operate "*under the authority and guidance of the Conference of the Parties (COP) serving as the meeting of the Parties to the Paris Agreement (CMA)*" (UNFCCC 2015).

The PA does not include modalities of whether or how to transition activities implemented, units issued, or methodologies and rules used under the KP to Article 6. The rules, modalities, and procedures (RMP) for the eventual design of Article 6 have been contentious among Parties at COP 24 and 25, and COP26 this year is tasked to achieve agreement.

With recent studies discussing transition options for activities and units under the KP (Lo Re and Vaidyula 2019; Lo Re and Ellis 2021; Fearnehough et al. 2021) and methodologies from the KP to the PA (Michaelowa et al. 2020a), one crucial and largely unaddressed question concerns the underlying characteristics of unused CERs[1] that would potentially be eligible for a transition to the post-2020

[1] For stylistic variance, used interchangeably with 'available CERs' throughout the report.

implementation period of the PA (in the following referred to as 'the post-2020 period'). Such information would be decisive for a well-informed decision of Parties to grant or restrict the transition of CERs into the post-2020 period. The question is closely tied to the potential transition of CDM activities which generate CERs and have been estimated to potentially supply some four billion CERs until 2020 (Lo Re and Vaidyula 2019 based on Schneider et al. 2017). The flooding of the market with CERs has failed to appear until today (issued CERs are over 2.1 billion as of April 2020). However, unused CERs in national Annex B[2] registries or the CDM registry and their underlying activities continue to generate debate in international climate negotiations.

Some Parties, including the Alliance of Small Island States (AOSIS), the Independent Alliance of Latin American and Caribbean States (AILAC) and the European Union (EU) reject any carry-over of KP units to the PA regime. One of the 'San Jose Principles for High Ambition and Integrity in International Carbon Markets'[3], which brought together over 30 countries at COP25 in 2019, "*prohibits the use of pre-2020 units, Kyoto units and allowances, and any underlying reductions toward Paris Agreement and other international goals*" (Dirección de Cambio Climático 2019). These Parties fear that a full transition of units could inhibit or delay new investments in mitigation activities in the post-2020 period (Lo Re and Vaidyula 2019). Indeed, permitting transition of CERs can decrease global GHG mitigation, decrease the price of other carbon credits thus decreasing overall market revenues but increase project owner´s profits (Fearnehough et al. 2021). The latter is why other Parties, especially Brazil, China, and India, argue for a full eligibility of unsold CERs under Article 6 and observers from these countries raise potential revenue loss for investors in carbon markets in host countries that have been highly active under the CDM (Burnwal, Bhatt and Gaurav 2021).

Several compromise options were proposed at COP25, e.g., restricting transition of CERs to projects and programmes registered after a certain cut-off registration date (dates discussed ranged between 2008 and 2016), limiting their use to the first half of the NDC implementation period (2023 or 2025) and/or only allowing CERs from certain activity types. However, in the end, no compromise has so far been found. One reason behind the lack of agreement was the uncertainty regarding the volumes and characteristics of CERs still available on the market (Michaelowa et al. 2020c).

In order to prevent repetition of the situation faced at COP25 this study builds on a dataset compiled by Betz et al. (2021) and aims to contribute to provide robust information on the remaining unused CERs. During our joint work by Perspectives and ZHAW, we have added other objectives to the analysis (see subsequent section 1.2 below). The study also builds on the Paris decision accompanying the PA expressing the desire to learn from the Kyoto Mechanisms in designing Article 6.

[2] It should be noted that Annex B is narrower than Annex I of the UNFCCC. With the Doha Amendment, the Annex B was amended, and the composition of the list changed: new countries were added to the list. In the remainder of this paper, we try to be as precise as possible in differentiating between Annex B and Annex I.
[3] At the Pre-COP25 in San José, Costa Rica, over 30 leading countries came together to agree on a set of principles to create a fair and robust carbon market. These 19 'high ambition and integrity principles', famously known as the San José Principles, were adopted by the countries which rule out double counting, ensure environmental integrity, enable highest possible mitigation ambition, prohibit use of pre-2020 units, Kyoto units and allowances toward PA and other international goals, among other principles.

1.2. Objective

Based on the dataset compiled by Betz et al. (2021), we assess the whereabouts of CERs issued until 2020, distinguishing between CERs cancelled and remaining CERs held, for instance in CDM or national registry accounts. This allows us to understand how many CERs from which host countries and what project types remain potentially eligible for transition into the post-2020 period. Based on this analysis, different options of a potential transition of units into the post-2020 period are discussed, including different cut-off dates. This includes an assessment of which host countries and private or public CER owners are particularly impacted by each option in order to understand likely positioning during the negotiations in the run up to and at COP 26. In addition, we distill lessons learned regarding reporting on CER holdings and transactions during the KP commitment periods (the first commitment period (CP1) from 2008-2012, CP2 from 2013-2020) and derive recommendations for reporting under Article 6 of the PA. These lessons particularly relate to transitions between the commitment periods, which are highly relevant in the context of NDC updates and revisions. They are also relevant regarding uses of ITMOs for purposes other than NDC compliance, e.g., in the context of voluntary carbon markets or the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).

1.3. Scope

The scope of this study is restricted to CERs, as they are the most widely traded type of carbon credits from the Kyoto Mechanisms (Michaelowa et al. 2019). In contrast to other Kyoto Mechanisms units, such as Assigned Amount Units (AAUs), Removal Units (RMUs) or Emission Reduction Units (ERUs) generated under Joint Implementation (JI), CERs are now also widely used for purposes other than compliance with Kyoto commitments. For reasons of materiality, non-permanent CERs from forestry activities that expire after a certain period, long-term CERs[4] (lCERs) and temporary CERs (tCERs)[5] are not discussed in this report. The volume of such CERs has been negligible to date, with an issuance of 20.76 million by December 31, 2020, or 0.99% of the total CER issuance (UNFCCC 2021b). The study also does not consider the trade of surplus Assigned Amount Units (AAUs), since the only Party publicly considering carrying over the surplus AAUs to achieve NDC targets is Australia, while stating in their updated NDC that new projections "*show Australia is on track to meeting and beat its 2030 target without relying on past overachievement*" (Australian Government 2020, p.1). No other Annex B country is currently considering carry-over or purchasing of AAUs. The definite surplus of AAUs from the CP2 will only be known after the true-up period, likely to be in 2023.

This report aims to cover all CERs issued between 9 November 2007, when CER issuance started, and the end of 2020. It must be noted that also after 2020, further CERs achieved before and during the KP's commitment periods (2005-2020) can be issued. However, we do not consider future potential supply of CERs as any estimation relies heavily on assumptions regarding the status of projects on the ground, including whether project participants did continue to monitor emission reductions and incur

[4] CERs for net anthropogenic removals by sinks from an afforestation or reforestation CDM activity or programme of activities. This type of CER expires at the end of the crediting period of the activity for which it was issued.
[5] CERs for an afforestation/reforestation CDM project activity which expire at the end of the commitment period in which they were issued.

significant outlays waiting for prices to pick up and then requesting issuance. For a discussion of potential future issuance of CERs that represent pre-2020 emission reductions for ongoing and active CDM activities, please see Ishikawa et al. (2020) and other sources discussed in section 3.1 below. It should be noted that not all potential issuances will materialize in absence of a strong demand signal for these CERs in post-2020 compliance or voluntary carbon market segments.

1.4. Structure of the report

Chapter 2 outlines the context and background information, especially relevant for readers not familiar with the details of governance and processes associated with the CDM and issuance of CERs as well as their trading, nor with the overall dynamics in the Kyoto carbon market and the most relevant CER supply and demand sources. Specifically, the chapter illustrates both governance structures and key processes of CER issuance, trading and use by non-state actors (subsection 2.3), final uses of CERs (subsection 2.4), the issue of carry-over between commitment periods as well as relevant data on demand and supply dynamics under the KP and its Doha Amendment (subsections 2.5 and 2.2). Chapter 3 summarises the results from an analysis of the status of CER issuances, transfers, and holdings to date to derive insights on activity-level implications of options to allow for CER use in post-2020 carbon markets under the PA. First, we discuss the underlying methodology, scope and data sources used both at aggregate level and project level (subsection 3.1). This is followed by a presentation of the core results (subsection 3.2), and their discussion in the context of relevant literature, negotiation processes and persisting empirical limitations encountered by the study (subsection 3.4). Based on these insights and further lessons learnt from the experience under the CDM, chapter 4 elucidates the major take-aways for the post-2020 PA era, including how to ensure transparency of ITMO holdings and prevent limitations of transparency due to overly strict interpretations of confidentiality (subsection 4.1), a discussion of alternative CER transition options to a registration-based cut-off date (subsection 4.2) and prospective infrastructure needs under market mechanisms foreseen under the Article 6 of the PA (subsection 4.3).

2. CER issuance, trading and use in the Kyoto Protocol era

In this chapter, we provide a brief overview of the history of international carbon markets since the signature of the UNFCCC. Moreover, we highlight key facts with regard to prices and volumes of CERs traded and governance structures and key processes under the CDM. Lastly, we introduce an overview of final uses of CERs and illustrate the process of 'carry over' between commitment periods.

2.1. A brief history of international carbon markets

The concept of carbon markets initially emerged in the 1990s with the first starting point being Article 4.2 of the UNFCCC on joint implementation of mitigation action by governments. While the idea of international carbon markets driven by 'dual benefit' of promoting the development of countries in the global South and reducing mitigation costs for developed countries was initially contested, it led to the formal adoption of the CDM under the KP in 1997. The KP set QELROs for 37 industrialized countries and economies in transition (EIT) as well as the European Union — also referred to as Annex B Parties to the Protocol. QELROs could henceforth be met through domestic climate action or use of emissions units generated by mitigation abroad through the three international carbon market mechanisms: CDM, JI and international emissions trading (IET). The CDM generates CERs from mitigation projects and programmes in developing countries and is subject to international oversight through the CDM Executive Board (CDM EB). One CER corresponds to the reduction of one tonne of CO_2 equivalent. JI is limited to projects or programmes in other Parties with commitments under the Kyoto Protocol. It has two tracks, track 1 being devoid of international oversight, while track 2 was overseen by the JI Supervisory Committee (JISC). Here, host countries issue Emission Reduction Units (ERUs) by converting them from Assigned Amount Units (AAUs) in their national GHG registry. This conversion avoided double counting the same mitigation outcome to both the host and buyer country commitments. Under IET, an international cap-and-trade mechanism, Annex B Parties with QELROs were now allowed to trade AAUs associated with the national emission quota. The mechanisms' implementation rules were agreed upon in 2001 in the so-called 'Marrakech Accords', and the KP formally entered into force in 2005.

International carbon markets under the KP massively expanded after the EU emission trading scheme (EU ETS) was linked to the CDM and JI, (Michaelowa et al. 2019). At the same time, critiques emerged, for instance concerning the unequal geographical distribution of activities as well as environmental integrity problems related to baseline setting and additionality (*ibid*). In 2011-2012, prices dropped drastically when the EU ETS (the main source of demand for Kyoto units) strengthened existing quantitative limits on the use of CERs and ERUs, prohibiting the use of credits from important activity types. Meanwhile, CER and ERU supply continued to increase. Demand also did not pick up due to the limited participation in the second commitment period (CP2) of the KP and low ambition in mitigation targets. Subsequently, international carbon markets were increasingly fragmented into activity type and geographical niches, driven by the emergence of a wide array of voluntary carbon market standards not subject to international oversight (*ibid.*, see also section 2.2.). Still, they continued to serve the KP until the end of its CP2 in 2020, with the final accounting due in 2023.

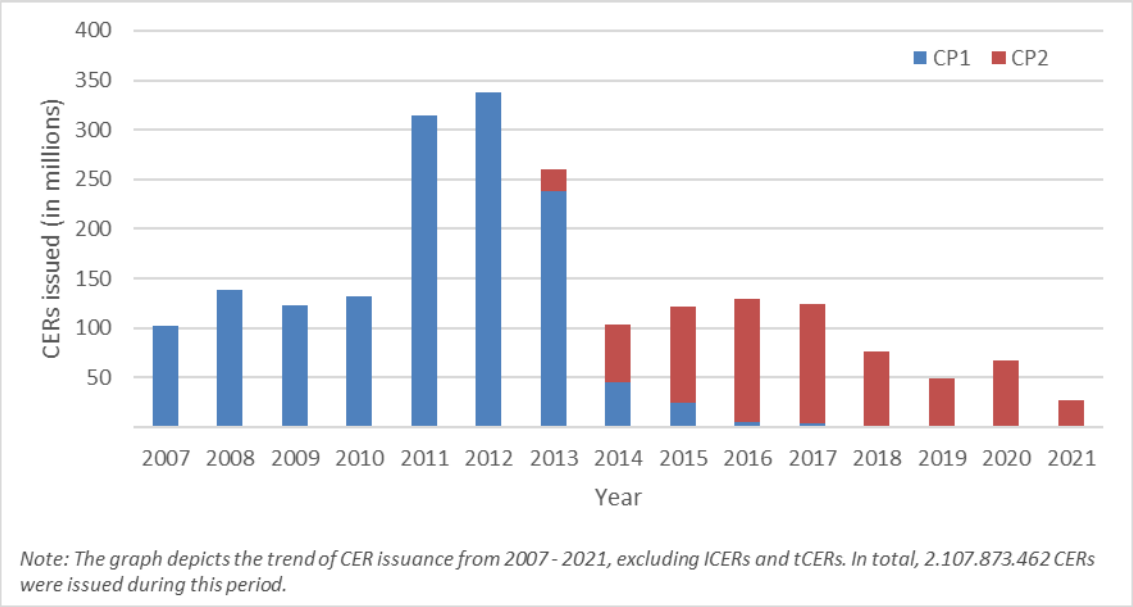
The adoption of the PA in 2015 marked a landmark turning point in the international climate policy regime. Article 6 of the PA introduces two forms of market-based cooperation: cooperative approaches between two or more countries (described in Article 6.2) and the establishment of a crediting mechanism in Article 6.4 for the generation of emissions credits. The latter was overseen by a Supervisory Body (SB) and was comparable to the CDM or the JI Track 2. The negotiations of the Article 6 rulebook are still ongoing after Parties failed to reach agreement in 2018 (alongside most other items of the 'Paris Agreement rulebook') and 2019. In 2020 no negotiations were held due to the Covid-19 pandemic, but informal discussions of Parties are underway to prepare for COP26 to be held in November 2021 in Glasgow. This reflects the controversies regarding lessons from the experience under the KP market mechanisms, including on the questions of how to safeguard the environmental integrity in carbon markets and to what degree activities and units from the KP should be allowed to transition into the post-2020 period (Lo Re and Ellis 2021). Despite the uncertainty of Article 6 rules, market-based cooperation through Article 6 is considered a vehicle for more ambitious NDC targets and has been increasingly integrated in NDCs, shown by the recent updates of NDCs (Brandemann et al. 2021).

2.2. Demand and supply in Kyoto Protocol carbon markets

Between 2008 (the beginning of CP1) and 2021, some 2.1 billion CERs have been issued (Figure 3). Issuance of CERs is market-driven, i.e., the propensity of project developers to pay issuance fees for new CERs depends on relative prices determined by demand and supply. Initially, demand for CERs and ERUs was driven by a few governments like the Netherlands purchasing them for use towards their commitments under the KP. In 2005, demand and prices began to rise sharply, following the EU's decision to allow their (limited) use towards compliance under the EU ETS, in place of more expensive EU allowances[6]. Switzerland's and New Zealand's ETS followed suit. This led to a massive private sector demand, and a completely unexpected spurt in development of activities. After its peak in the second half of the 2000s, this 'gold rush' (Michaelowa and Buen 2012) from 2012 onwards was followed by a massive decline in CER demand and prices (Figure 4). This sudden change in fortune was due to NGO criticism of the Kyoto mechanisms leading to CER import bans as well as the impact of the financial crisis and the consequent fall in demand for credits from ETSs and governments alike (Michaelowa et al. 2019). With a delay of one year, this led to a decline in CER issuance (Figure 3).

[6] In the past, the companies subject to the EU-ETS have been the largest buyer of CERs. However, companies are now coming close to the overall maximum level of allowed use of Kyoto mechanism credits, which has been set at 1.568 billion credits. 1.538 billion credits were used (surrendered until 2012, exchanged for EUAs since 2013) by the end of 2019, of which 0.964 billion were CERs (Nissen et al. 2020, p.29 f.). Given that the actual use of CERs will be finetuned until the very last moment of compliance with 2020 ETS caps, the remaining small difference of 30 million will certainly be covered, as CERs are orders of magnitude cheaper than EU allowances. Until 2013, CERs could be directly surrendered for compliance with EU ETS requirements. These CERs were thus accumulating on government accounts and generally used for compliance with CP1 targets. CERs not surrendered were 'frozen' in private actor accounts and de facto expropriated (see a discussion on carry-over and cancellations of unused CP1 CERs in this study). The EU never banked any CERs, as the Doha Amendment only entered into force in late 2020. Since 2013, CERs had to be formally exchanged for EU allowances.

Figure 3: Issuance of CERs by year and commitment period



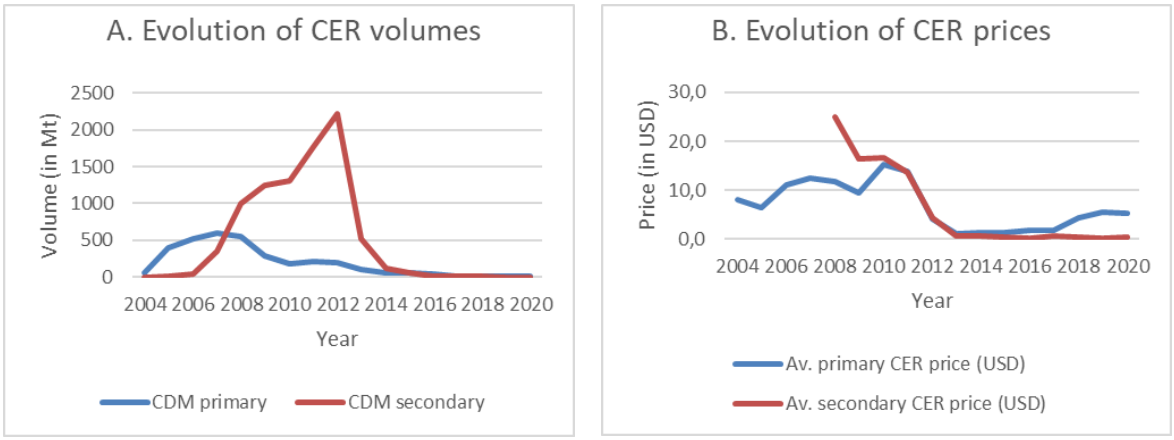
Note: The graph depicts the trend of CER issuance from 2007 - 2021, excluding lCERs and tCERs. In total, 2.107.873.462 CERs were issued during this period.

Source: authors, based on CDM Registry Issuance Report as of 30 April 2021 (UNFCCC 2021b).

This market crash occurred at a point in time where developing countries with limited financial and administrative resources (e.g., Least Developed Countries (LDCs) and African countries) had built their capacities to access the CDM, so activities continued to be registered and issuances requested. Therefore, the UNFCCC Secretariat and CDM EB focused more strongly on ensuring CERs were used in the context of results-based climate finance and voluntary offsetting through promoting the 'voluntary' cancellation of CERs (Michaelowa et al. 2019). In September 2015, the UNFCCC Secretariat launched an online platform for voluntary cancellation[7] of CERs to allow for members of the public to offset their emissions. On this platform, both CP1 and CP2 CERs from either the pending account or a personal holding account in the CDM Registry (see section below for a description of the account structure) can be marketed by the project participants, after the adaptation and administration tax (share of proceeds, SoP, see Box 2 below) has been paid (UNFCCC 2021a).

[7] The 'United Nations Carbon offset platform' is available via the following link: https://offset.climateneutralnow.org/ (accessed February 6, 2021)

Figure 4: Evolution of CER trading volumes and prices by market segment



Source: authors, based on CDM Registry Issuance Report as of 30 April 2021 (UNFCCC 2021b) and own analyses.

A handful of governments, including Sweden and Norway, continued to purchase CERs and voluntarily cancel them as an 'ambition raising measure' and contribution to climate finance. Germany has launched the Nitric Acid Climate Action Group (NACAG) that purchases CERs from abatement of N_2O from the production of nitric acid. Multilateral institutions also continued to purchase CERs and cancel them, e.g., the World Bank through the Carbon Initiative for Development (CiDEV) and the Pilot Auction Facility (PAF) (Espelage et al. forthcoming).

Japan, a CER buyer in CP1, initiated the development of the Joint Crediting Mechanism (JCM) bilaterally with various developing countries as a bilateral, more flexible and streamlined alternative to the CDM (ADB 2016). Japan heavily criticized the CDM for its strict and complex rules on additionality, long lead times in processing, exclusion of nuclear power projects and uneven sectoral and geographical distribution of limited contributions to sustainable development (see detailed discussion in Kachi et al. 2014, p. 63ff). Japan did not participate in CP2 and thus could not use the CDM from 2013 onwards for its international mitigation cooperation.

China, as the largest originating country for CERs, defined its own Chinese Certified Emission Reductions (CCERs), heavily based on the CDM. For instance, CCERs could be issued for projects approved by the Chinese DNA as CDM projects, but not registered by the UNFCCC (see Zhang and Arup 2015). CCERs are eligible to a limited extent as offsets in the seven-provincial pilot ETS schemes and in the recently launched national ETS (see ICAP 2021).

Other developing countries created their own sources of demand for CERs. South Korea allows for a limited degree of emission offsetting with CERs under certain conditions under its Korean ETS (KETS). CERs must be cancelled in the CDM registry to be converted into Korea Credit Units (KCUs) (ADB 2018, p. 22). Taiwan also aims to acquire CERs through cancellation in the CDM or Annex B national registries. It is, however, unclear to what extent CERs have been used to date (Chien 2014, Chen 2019).

Both Colombia and South Africa allow for domestic CER use against carbon tax compliance, based on the attestations of voluntary cancellation in the CDM registry. Thereby, both countries established a national source of demand for their local CDM activities. In Colombia, 5.0 million CERs had been cancelled by December 2020; in South Africa 3.4 million (UNFCCC 2020c). Mexico allows the undertaking of carbon tax payments through the value-equivalent surrender of CERs. This is not attractive and thus not relevant. Brazil and India, the largest CER originating countries after China, have neither established nor foreseen demand sources for CERs through the creation of domestic carbon markets.

Compounded by the uncertainty of adoption of the rules of the Doha Amendment, JI ceased to issue significant volumes of ERUs in the CP2.

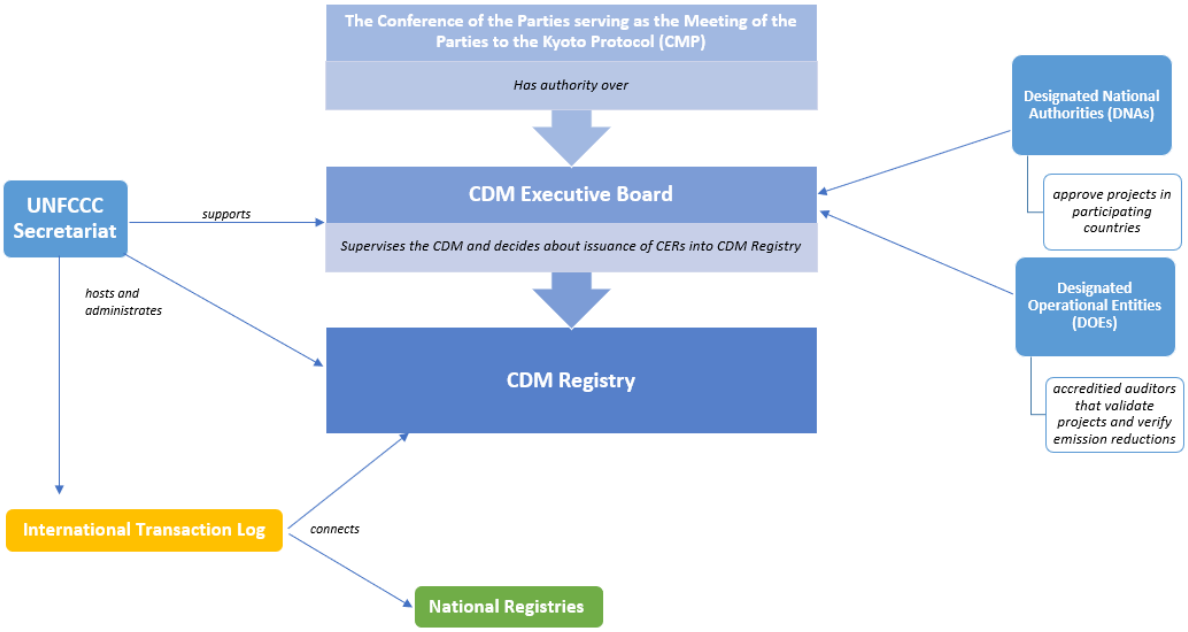
2.3. Governance structure and key processes in CER trading and use

Understanding the governance structures and processes under the CDM is key in understanding and informing potential transitions of activities and CERs and help to design the governance structures and processes under the PA 6.2 and 6.4 mechanisms, based on lessons learned in these institutions.

The supreme body of the CDM is the COPs serving as the meeting of the Parties to the Kyoto Protocol (CMP). Similarly. under the PA, this overarching authority is mirrored by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement (CMA). The CMP guides CDM EB actions. The CDM EB oversees the CDM and is supported by the UNFCCC Secretariat, which hosts and administers the CDM registry and the International Transaction Log (ITL) that connects the CDM registry with national registries (Box 1).

In designing a smooth transition, institutional coordination between key actors will be a central element and several coordination options have been highlighted (Lo Re and Ellis 2021). While some actors will remain the same (e.g., host Parties and project participants), other new institutional bodies appear under the governing the Article 6 mechanisms, notably the CMA and the Article 6.4 SB.

Figure 5 - Institutional governance of the CDM



Source: authors.

Box 1: Transaction logs under the KP

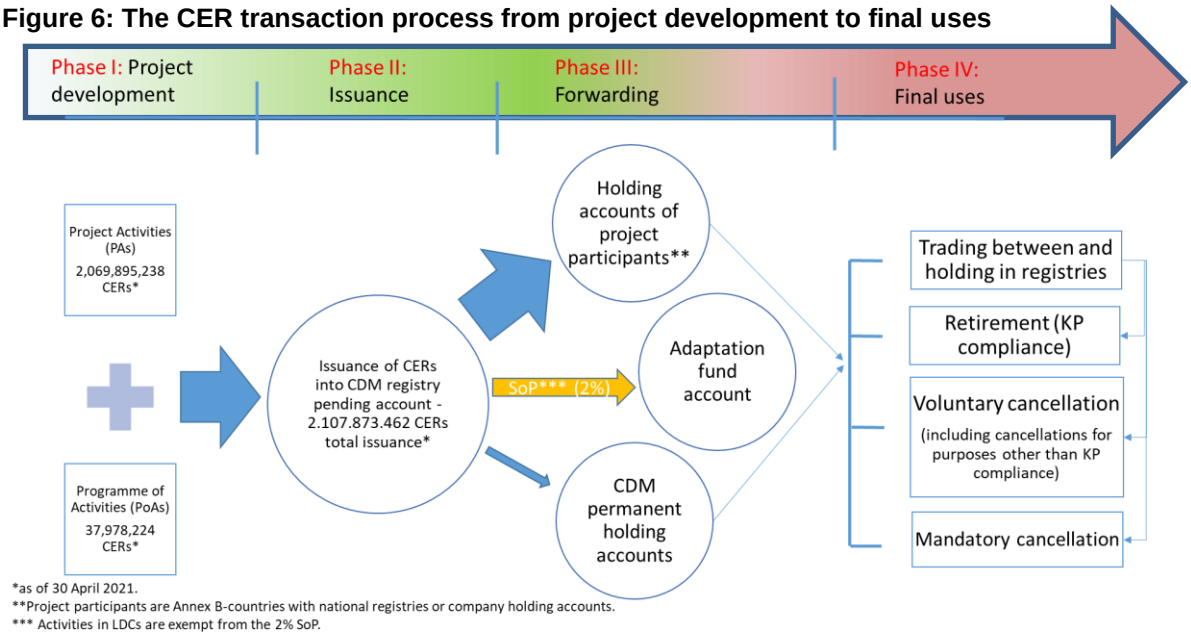
The CDM registry and national registries are connected via the **International Transaction Log** (ITL) whose core mandate is to ensure accurate accounting and verification of unit transactions proposed by registries involved in the emission trading mechanism defined under the KP and its Doha Amendment. The ITL is put in place and administered by the UNFCCC Secretariat and publishes annual reports to support the reviewing and compliance process under the KP. If, for instance, a national registry wants to engage in inter-registry trade or carry-over units into a subsequent CP, it needs to first send a request to the ITL. This proposal is then assessed against a set of pre-defined checks and granted or rejected. The ITL publishes aggregate (i.e., excluding project-level information) transactions annually with a time lag of two to three years (e.g., see the ITL's most recent publication (UNFCCC 2018)).

In addition, Annex B Parties may establish supplementary transaction logs (STLs) to monitor and verify the validity of transactions where such transactions are subject to regional or supranational trading schemes. An example of such an STL would be the European Union Transaction Log (EUTL). These STLs must operate in a manner consistent with KP modalities for accounting of Kyoto units.

Source: Authors and UNFCCC (2018; 2021c).

The governance as described above has led to the emergence of a 'CER transaction process'. Its key processes include the initial project development, issuance of CERs, primary sale, secondary transactions, retirement, or cancellation in different contexts. In a simplified manner, this process can be summarized as shown in Figure 6. Please note the volume of CERs issued to date:

Figure 6: The CER transaction process from project development to final uses



Source: Authors. Note: SoP - Share of proceeds.

After successful registration, emission reductions from these activities are monitored, reported, and verified **(Phase I).** Upon verification of the emission reductions by a designated operational entity (DOE), the CDM EB issues CERs into a pending account in the CDM registry **(Phase II).** This implies payment of an issuance fee (part of the share of proceeds (SoP), see Box 2). The CDM registry is a platform under the authority of the CDM EB and operated by the UNFCCC secretariat. It serves the purpose of issuing CERs and distributing them to national registries. This central registry records mitigation activities from the moment they obtain the letter of approval from the respective host country and request validation from an auditor, called the Designated Operational Entity (DOE). Subsequently, after payment of the SoP, (see Box 2), CERs can be forwarded to CDM permanent holding accounts in the CDM registry or through the ITL to national registries of Annex B Parties **(Phase III).** Lastly, CERs can be traded within the CDM registry or within and between Annex B national registries. CERs are 'used' and no longer tradeable once they are retired, voluntarily cancelled (which includes cancellations for a wide range of purposes other than Kyoto Protocol compliance) or mandatorily cancelled (e.g., remaining CERs in a national registry that are not carried over) (**Phase IV)**.

Box 2: The share of proceeds under the CDM and lessons for the 6.4 mechanism

The **'share of proceeds' (SoP) is a tax on market mechanism activities and/or emission credits** introduced under the CDM for administrative purposes ('monetary SoP') as well as to cross-finance adaptation activities through the Adaptation Fund (AF) ('in-kind SoP', i.e., in the form of CERs). The administration SoP is levied upon issuance of CERs into the CDM registry according to a staggered formula, starting with USD 0.10 per CER for the first 15,000 tons of carbon dioxide equivalent (tCO_2e) emission reductions for which issuance is requested in a given calendar year, and increasing to USD 0.20 per CER for any amount more than 15,000 tCO_2e in that same year.

The adaptation SoP is levied upon forwarding of units, e.g., to national registries. The adaptation SOP requires an in-kind share of 2% of forwarded CERs, transferred to an account of the AF, from which the World Bank as trustee monetizes them to mobilize funding for the fund. CDM activities in LDCs are exempt from the SOP.

This differentiation led to starkly contrasting outcomes, due to the sudden drop of prices for CERs, which significantly reduced the revenues for the AF from selling CERs. Conversely, the monetary administrative SOP continued to generate huge revenues (USD 356 million as of 2019), given the stable growth of the CDM activity pipeline. This exceeded actual administration costs by far and allowed the extensive CDM administration to continue for almost a decade despite the crash of Kyoto unit markets.

Recognizing the importance of levying a tax for both administrative purposes as well as adaptation activities (which, due to limited bankability, are less suitable for the inclusion in competitive credit generation activities), one major lesson learnt is that monetary SoP can become 'sticky' without the provisions of adjustment mechanisms according to market developments.

The negotiations on Article 6 took up the issue of the SoP, while its application to Article 6.2 cooperative approaches remains contentions. Even for the Article 6.4 mechanism, most technical questions remain open, including the relative size of monetary versus in-kind SoPs, the level of the in-kind SoP and the point of taxation.

Source: Authors and Hoch et al. (2019).

2.4. Final uses of CERs

Unfortunately, international terminology for the use of CERs is applied in a sloppy manner. We thus describe the official terminology in detail. On a general note, used CERs refer to CERs that have been cancelled or retired, whereas unused CERs have been issued and remain potentially available for use (Lo Re and Vaidyula 2019). In the remainder of this study, we will adhere to this distinction unless otherwise specified. There are two other important differences between used and unused CERs. While used CERs necessarily imply that all administrative fees have been paid and CERs for the AF have been levied, unused or available CERs can still be in the pending account of the CDM registry. This implies that some SoP has not been paid yet by project participants, in particular adaptation SoP. Note that the attribute 'unused' or 'available' does not mean that CER units have not been sold yet. While this *can* be the case, it can be suspected that programme developers only have an incentive to request issuance and pay related fees if they are confident they can sell the CERs, especially for recent projects and issuance in the context of a low demand (with some increased demand signals from the voluntary carbon market very recently). Our definition of 'available' CERs is distinct from 'potential' future CER issuances that may be prompted from ongoing projects in the case of a demand signal, discussed in Ishikawa et al. 2020 and not subject to analysis in this report.

In the KP language, different forms of CER use exist. The most important one is the 'retirement' of CERs, implying a transfer of units to a retirement account in a national registry. This enables the Party

to account for that unit toward its QELROs under the KP. To retire CERs, an Annex B country must fulfil the eligibility criteria for participation in the CDM.

'Voluntary' cancellation means the placement of a unit in an account which subsequently prevents the unit from being used by an Annex B Party for compliance with its commitments. Thus, we now must differentiate between Annex B and non-Annex B countries. If a **national registry** of an Annex B country reports 'voluntary cancellations' of CERs to the CMP, the units held in the respective accounts may have very well been used for compliance with national or supranational law, or for voluntary offsetting purposes (SBSTA 2005). CERs may be placed in the **CDM registry's** voluntary cancellation account by entities that want to voluntary offset emissions or that use the cancellation attestation in the context of results-based climate finance or national carbon pricing policy instruments in Non-Annex B countries, e.g., in the context of the Colombian or South African carbon tax.

In accordance with decision 19/CP7, 'mandatory' cancellation of units must be undertaken for all Kyoto units created in a certain commitment period after this commitment period has ended (SBSTA 2005). Only units that were carried over to a subsequent commitment period in accordance with CMP decisions are exempt. For a further discussion of this, please see subsection 4.2.1 below.

Other forms of cancellation of CERs include cancellation for land-use, land-use change and forestry (LULUCF) activities, when they are found to be a net source of emissions in Annex B countries (the so called 'cancellation of activities' under Article 3, paragraphs 3 and 4). In addition, there can be administrative cancellations for excess or erroneous issuance of CERs.

Table 2: Summary of final uses of CERs

Uses of CERs	Description
Retirement	Transfer of units to retirement account in a national registry.
Voluntary cancellation	Placement of a unit into an account which prevents the unit from being used by an Annex B Party for compliance with its commitments; can be placed either in national registries of Annex B parties or CDM registry.
Mandatory cancellation	Undertaken for all Kyoto units created in a commitment after the said commitment period has ended, except for the units carried over to the next commitment period.
Other types of cancellation	Includes administrative cancellations to correct for excess or errors in issuance of CERs; can also include cancellations for LULUCF activities when such activities are found to be net emission sources in Annex B countries.

Source: Authors.

Neither 'cancellation' nor 'retirement' should be treated synonymously with the term 'surrendering'. Surrendering of Kyoto units only takes place in the context of national policy instruments, e.g., an ETS. Units surrendered by an entity to its respective government can be held in the government's holding

account, cancelled for different purposes or retired by the government in its national registry. There is no direct link between the 'surrendering' of units in a national context and accounting under the KP[8].

2.5.Carry-over of CERs

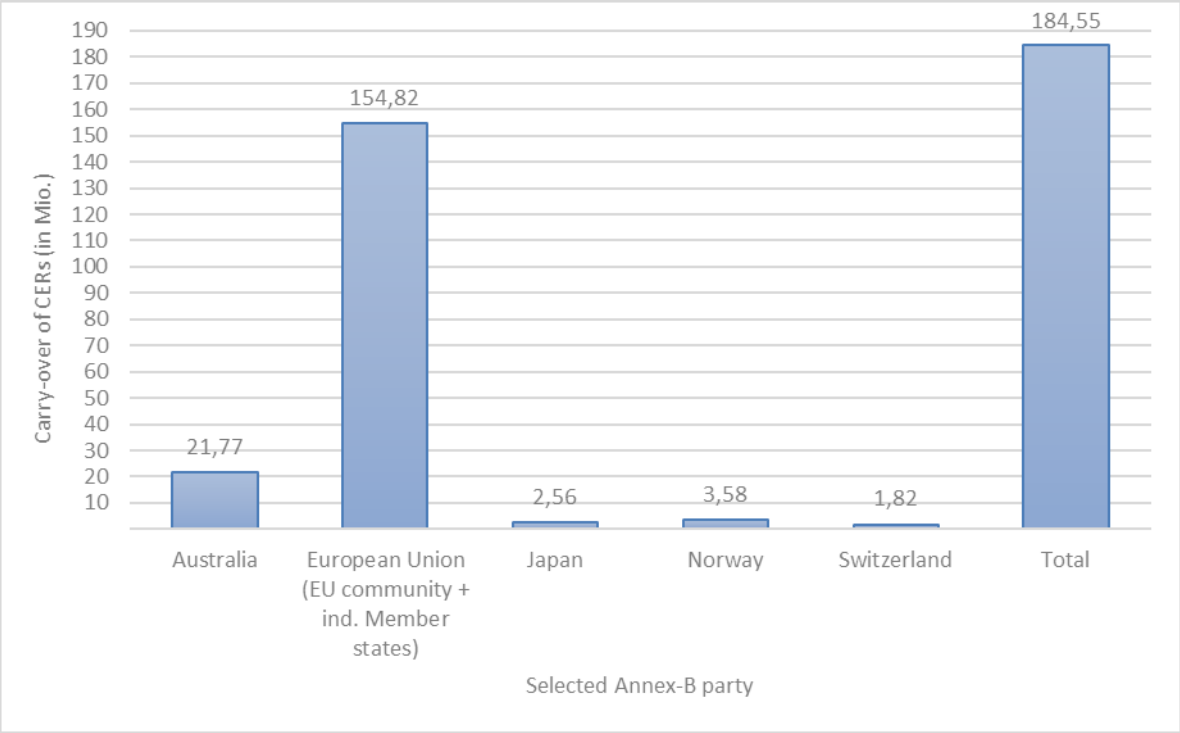
Carry-overs of unused units between KP commitment periods are limited to 2.5% of each Party's emissions budget (UNFCCC 2006b, p.27). The Doha Amendment, regulating CP2, stated that all Annex I Parties, including those without emission targets in CP2, may continue to participate in CDM projects and receive CERs forwarded from the CDM registry to accounts in their national registry. However, Parties without QELRO for CP2 cannot transfer CERs to other national registries or acquire CERs from other national registries (UNFCCC 2012). The problem here was that CP2 only in October 2020 achieved ratification by enough Parties leading to the last-minute entry into force of the Doha Amendment on December 31st, 2020. This meant that during the entire CP2, no Party with QELROs inscribed in the Amendment to the Annex B[9] could be certain that the compliance with its commitments would be subject to a ratified treaty under binding international law. What further weakened CP2, and with that the entire climate policy regime, was the fact that Parties with QELROs under CP2 only represented less than 13% of global GHG emissions (Crippa et al. 2019).

The real-life implications of the Doha Amendment's restrictions on carry-over and for enforcing CP2 are limited as most Parties with a CP2 commitment are on track to overachieve their targets and cancel surplus units. Switzerland (as the only exception) has acquired sufficient Kyoto units for compliance.

Carry-over of CERs between CP1 and CP2 co-determines the available stock of CERs potentially eligible for transition into the post-2020 period. Figure 7 summarizes the requests of carry-overs of CERs from CP1 to CP2 of selected Annex-B countries:

[8] In the EU, surrendered CERs held in the EU ETS cannot be transferred out of the EU ETS for sale for other uses, to avoid double use through the secondary market. The registry was reformed to forbid such transactions, after the Hungarian government had (legally) sold 800,000 surrendered CERs to non-European investors which then made their way back into the EU-ETS (see Branger et al. 2015).
[9] This refers to the "Doha Amendment", adopted on December 8th 2012 in Doha, Qatar.

Figure 7: Carry overs of CERs from Annex B countries (millions)



Source: Final compilation and accounting reports (UNFCCC 2016 a-d).

An analysis of characteristics shows that the top three most important projects are hydrofluorocarbons (HFCs) with 25.7% of all CERs carried over (43.57 million CERs), wind projects with 18.8% (31.93 million CERs) and N_2O projects with 15.2% (or 25.69 million CERs). About half of these carry-over CERs come from China (49.3% or 90.87 million), followed by India (16.4% or 30.18 million CERs) and Brazil (7.0% or 13.52 million CERs).

At the end of a commitment period, CERs can only be traded into or out of accounts in national registries of Annex B countries until the end of the 'true-up period'. This true-up period is defined as extending 100 days after the date agreed by the Parties for completing the reviews of Annex B Parties' emission inventories for the final calendar year of the commitment period (UNFCCC 2005a, Annex, section XIII). For CP1, the end of the true-up period was determined to be 18 November 2015. For CP2, no date has been set yet, but it is expected to be in 2023.

After the end of the true up period, only CERs 'carried over' into the new CP can be traded further among Annex B countries (the only exception for 'old' CERs is voluntary or mandatory cancellation). At carry-over, the serial number of the units gets updated to document the eligibility for the new CP. All CERs not carried over must be mandatorily cancelled (UNFCCC 2005b, paragraph 36; SBSTA 2005).

While this all looks good at first glance, the problem is that there is no deadline for Parties to finalize the carry-over process. Therefore, no Party to date has reported to have finalized its carry-over and New Zealand is the only Annex B country to have mandatorily cancelled all remaining CP1 CERs in November 2020 (World Bank 2020). All Annex B Parties continue to report on their CP1 Kyoto units in

standardized electronic formats[10]. This results in the continued holding of CP1 CERs in national registries even after the true-up period was finalized and all accounting is done, presumably because it is problematic for national governments to cancel CERs that belong to private entities. Very differently to what the CMP decision had envisaged, CP1 CERs therefore continue to be held in national registries on Party and entity accounts in the year 2021. However, they are basically 'zombie' units in the KP system (Box 3).

Box 3: 'Zombie CERs'

'Zombie CERs' are CERs held in national registries after the end of the true-up period of their respective associated commitment period that cannot be transferred outside the national registries anymore and may only be transacted within the registries, e.g., being 'voluntarily cancelled' (though that may include mandatory transactions under national law). Such CERs have not been requested for carry-over or are 'excess CERs' of the 2.5% limit and must be mandatorily cancelled as soon as the Party administering the registry has completed the carry-over process (UNFCCC 2006b, p.27).

In its annual reports from 2017 and 2018, the ITL administrator requested guidance from the SBI on finalizing the data exchange standards, as divergent views on implementing the carry-over process for Annex I Parties without target for the second commitment period meant that the work could not be completed (SBI 2018a, paragraph 6). At the subsequent 49th session of the SBI, no further guidance was provided (SBI 2018b).

CP1 CERs that are held in the CDM registry are not subject to the automatic cancellation procedure that applies to CERs that are held in Annex I Party registries. They may continue to be held in the CDM registry, transferred within the CDM registry and voluntarily cancelled in the CDM registry after the end of the true-up period (CDM 2021). There is also no deadline for the issuance of CP1 CERs, as the CDM EB has not (yet) set a deadline for receiving requests for issuance of CP1 CERs.

Here, we would like to stress that the carry-over of CERs from a CP to the post-2020 period under the PA is not subject to the rules defined for carry-over of CERs under the KP as the post-2020 implementation period of the PA is not a subsequent or additional commitment period. Rather, the PA represents an entirely new climate regime which needs to formulate its proper rules for transitioning of units. The Doha Amendment thus has no impact on the carryover of Kyoto units for use in the post-2020 period. Therefore, the Doha Amendment leaves the question of eligibility of CERs for the post-2020 period open to ongoing negotiations about qualitative and quantitative restrictions under Article 6.

[10] The submissions of SEFs are available here: https://unfccc.int/ghg-inventories-annex-i-parties/2020 (accessed February 6, 2021)

3. Quantitative analysis of unused CERs

In this chapter, we introduce the methodological procedure as well as the results from our quantitative analysis of the volumes, characteristics, and whereabouts of unused CERs potentially available for transition into the post-2020 period, based on a dataset by Betz et al. (2021). The results of the study and its limitations due to data availability gaps are discussed against the background of existing research. This analysis provides an evidence base to guide negotiators in the run-up to COP26 toward making informed decisions about prospective transition options in negotiations on eligibility of CERs in post-2020 carbon markets as well it shows the limits of standardized reporting and transparency requirements.

3.1. Scope, methodology and data sources

To date, two reports have quantitatively analyzed unused CERs with regards to a potential post-2020 transition (Lo Re and Vaidyula 2019) or with respect to satisfying future demand for CERs, e.g., through CORSIA (Fearnehough et al. (2019). Both studies relied on data from the CDM registry and annual Standard Electronic Format (SEF) submissions to the UNFCCC.

Fearnehough et al. (2019, p. 35) assess CDM and national registry holdings and report combined holdings of about 400 million CERs available for use by mid-2018.[11] In the context of ongoing negotiations under Article 6.4, Lo Re and Vaidyula (2019) discuss different options of transition of activities and units from the CDM to the post-2020 period. By December 31st, 2018, they calculate the stock of unused CERs at some 819 million CERs, or 41% of the total amount of CERs issued by the cut-off date (*ibid*., p.30). The difference of a factor of two in the reported estimates of holdings of unused CERs between these studies can at least partially be explained by different cut-off dates of analysis, and hence the use of different data sources. While Fearnehough et al. (2019) consult SEF tables with a cut-off at the end of 2017, as well as holding data from the CDM registry (cut-off mid-2018), Lo Re and Vaidyula (2019) use SEF tables from the subsequent year to deduct all used CERs (e.g., cancelled or retired) from all issued CERs as per CDM registry data at the cut-off at the end 2018. Lo Re and Vaidyula (2019) illustrate the following balance equation (Equation 1):

Equation 1: Balance equation to calculate the volume of available CERs

$$Volume\ (v)\ of\ unused\ CERs =$$

$$V_{Total\ CERs\ issued} - V_{cancellation,CDM} - V_{retirement,Annex\ I} - V_{cancellation,Annex\ I} - V_{replacement,Annex\ I} = V_{holding,CDM} + V_{holding,Annex\ I}$$

Source: Authors based on Lo Re and Vaidyula (2019).

[11] About 136 million CERs in national registries and about 265 million CERs in the CDM registry pending and holding accounts. Issued CERs in the CDM accounts likely have no buyer yet and await payment of the SOP, whereas holdings in national registries could potentially more swiftly satisfy new sources of demand, such as from CORSIA (*ibid*.). However, the use of CERs for CORSIA is restricted to those held in the CDM registry (note from the authors).

The left side of this equation estimates the volume of unused CERs through what can be called 'backward induction approach', i.e., subtraction of all units retired and cancelled from total CERs issued at a given cut-off date. The right side of the equation represents the sum of all holdings at a given cut-off date. In theory, both sides of the equation should be equal. Whether this is the case or not was, however, left open in Lo Re and Vaidyula's (2019) analysis. Nonetheless, their conceptual approach is deemed more appropriate than the one by Fearnehough et al. (2019), as reporting on holdings in SEF tables is incomplete. In our view, summing up holdings does not allow to exactly estimate the unused CER volumes since Annex B Parties do not sufficiently report on the impacts of their (open-ended carry-over) process. This means that a certain number of holdings in government accounts (CP1 units which were not carried over) are de facto frozen and no longer available for use. Under the current reporting undertaken by Parties, Equation 1 thus only theoretically holds true. Therefore, we understand that if Parties comply with the Kyoto Protocol, not all held CERs as estimated by Lo Re and Vaidyula (2019) to be still available for use and deem the amount of unused CERs as concluded by Lor Re and Vaidulya as too high. We illustrate the likely level of overestimation in section 3.2.

To our knowledge, no study assesses the distribution of ownership of unused CERs among Annex B Parties, nor other features of unused CERs relevant for negotiations, such as the type of projects, the host countries in which they are located, their registration dates or vintages.

Our analysis primarily relies on the left side of the balance equation postulated by Lo Re and Vaidyula (2019), which we refer to as the 'backward induction approach'. At the aggregate level, we can correct for the CER volumes frozen once the carry-over process is completed[12].

Betz et al. (2021) compiled the most recently available UNFCCC data from the SEFs and the CDM registry (UNFCCC 2021a-d; IGES 2020a-c) for April 2021. Where possible, the dataset was complemented by project-specific data which has been requested from and made available by national registries, albeit to a varying extent, to differentiate by the project types, registration dates, CER vintages and host countries. This permits a deeper understanding of the whereabouts and the underlying characteristics of CERs.

Due to confidentiality requirements, the dataset is not publicly available, and we only publish aggregate numbers for project types. We would like to stress that data availability gaps have an impact on the robustness of our absolute numbers. We also stress that we do not consider potential future issuance, as has been attempted by various other studies, including Schneider et al. (2017), Ishikawa et al. (2020) and Fearnehough et al. (2021)[13].

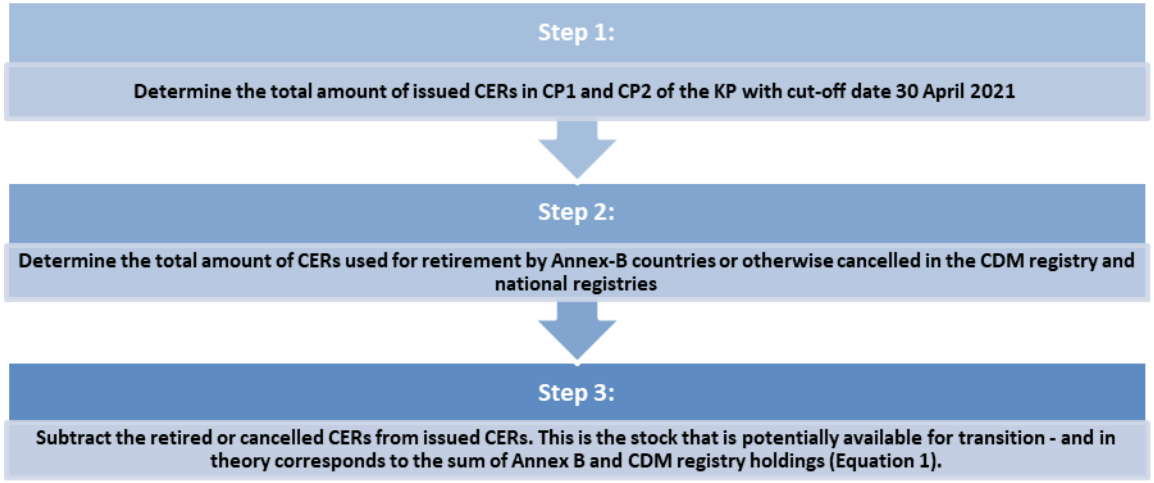
[12] We would like to note that as we do not consider issued lCERs or tCER volumes in replacement accounts of Annex B Parties, they are not included in the analysis. These volumes are immaterial; Lo Re and Vaidulya (2019, p.43) include CERs from replacement accounts but find that no Party indicated non-zero holdings in replacement accounts.
[13] These estimates depend on many assumptions regarding CER prices, 'survival rates' of projects, the share of projects that have renewed their crediting period before the September 2020 deadline and continued their monitoring. Ishikawa et al. (2020) estimates a potential future supply of 320-340 million CERs for activities registered on or after 1 January 2008 and of 46-63 million CERs for activities registered on or after 1 January 2016. However, these estimations include estimations of already issued CERs, so a direct comparison is not possible or incorporation of these numbers into our analysis is not possible.

Our analysis is undertaken on two levels: the aggregate level (subsection 3.1.1) and the project-specific level (subsection 3.1.2). The creation of this two-level structure stems from the distinctive use of datasets. While the aggregate analysis is performed by using publicly accessible information only and is meant to give an overview on the *amounts* of CERs available, the disaggregated information at project level of both unused and used CERs focuses on the underlying project characteristics. Data limitations do *not* allow for a definite allocation of specific CER volumes to the unused and used categories. We engaged as much as possible with national registries from Annex B countries to obtain complementary disaggregated data, which is usually not available to the public, constituting a clear non-compliance with CMP decisions (see our discussion in section 4.1). To respect confidentiality provisions at the UNFCCC level and in different national jurisdictions, we consulted with the relevant stakeholders before releasing the information made available to us and presented herein. Note that the results presented in the following sections may not add up due to rounding.

3.1.1. Aggregate level

We apply the following three-step procedure to determine the current stock of available CERs at the aggregate level, subtracting the amount of used CERs (retired and cancelled) from total CERs issued. This process uses the most recent data on issuance and holdings from the UNFCCC (2021a, d) and for used CERs (retired and cancelled) from IGES (2020a, b) under the 'backward induction approach' of Equation 1 (Figure 8):

Figure 8: Stepwise procedure to calculate aggregate stock of unused CERs



Source: authors.

In an ideal world with full transparency and traceability of all Kyoto units in real time, the difference between all issued CERs and all used CERs would equal the exact amount of issued but unused

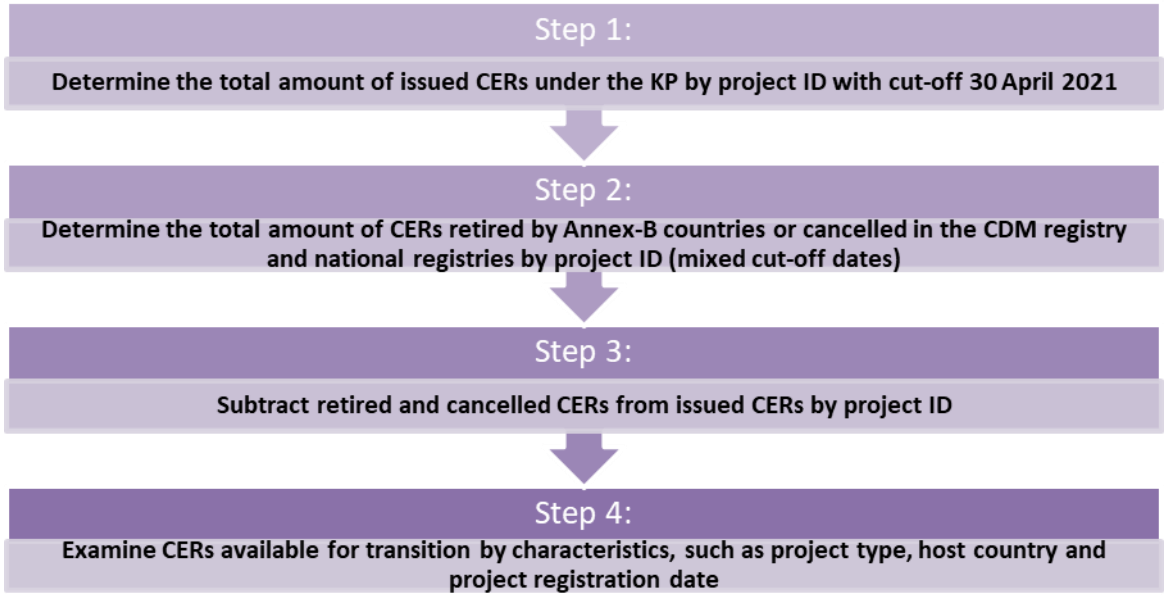
Fearnehough et al. (2021) estimate the potential volume of GHG emission increase resulting from transition options. They estimate that a transition without restrictions leads to a credit potential of 962 Mt CO2e and thereby an estimated emissions increase of 763 MtCO2e. A 2016 registration cut-off would lead to a potential credit supply of 269 Mt CO2e and a potential emission increase of 139 MtCO2e. Their assessment of supply follows the same model of Ishikawa et al. (2020) and thus suffers from the same limitations and uncertainties which apply to it. We invite readers to complement our results with the results of these studies if they wish.

holdings. In our suboptimal world of limited transparency, we cannot conclusively tell whether this balance equation holds true. This disaggregated information necessary lies with the ITL, tasked under the KP to take account of all transactions, and is not available to the public, not even after a time lag.

3.1.2. Project level

We apply a four-step procedure to analyze the stock of unused CERs that is potentially available for a transition to the post-2020 period at a project-specific level (see Figure 9 below):

Figure 9: Stepwise procedure to determine the stock and characteristics of unused CERs



Source: authors.

Step 1-3 correspond to the procedure depicted in Figure 8, however we can now distinguish between project IDs by merging publicly available and data provided by several governments. Step 4 thus permits assessment of unused CERs according to project type, host country and project registration date.

This novel analysis combines the most recent aggregate-level data releases on holdings, final uses and carry over from April 2021 (UNFCCC 2021a, b, d) with project level information by IGES (2020a-c), including disaggregated project-specific data - project type, host country and project registration date (requested from and made available by (some) national registries[14]). For each Party's CER uses and holdings, in this analysis, the most recent value available is used.

Based on the above-mentioned steps and considering the cut-off date at project-specific level, this procedure can be expressed by the following equation (Equation 2):

[14] The supplementary data by national registries was provided with different cut-off dates, notably for the European Union transaction log and Switzerland (data as of 30 April 2018), New Zealand (as of 10 May 2021) and Japan (as of 31 January 2021).

Equation 2: Equation for the volume of unused CERs at project-specific level and with varying cut-off dates

$$Volume\ (v)\ of\ unused\ CERs\ by\ project\ (i) = V_{Total\ CERs\ issued,\ i} - V_{cancellation\ CDM,\ i} - V_{retirement\ Annex\ B,\ i} - V_{cancellation\ Annex\ B,\ i} = V_{holding\ CDM,\ i} + V_{holding\ Annex\ B,\ i}$$

Source: authors. Note: Unlike Lo Re and Vaidyula (2019), we speak of Annex B Parties, rather than Annex I Parties, reflecting the fact that only Annex B Parties with QUELROs can retire CERs. Cancellation in the CDM registry includes administrative cancellation.

Data sources and related cut-off dates used in the study are shown in Table 3:

Table 3: Data sources and cut-off dates for the components of Equation 2

Component	Sources and cut-off dates
$V_{Total\ CERs\ issued}$	UNFCCC (2021b) as of 30 April 2021.
$V_{cancellation\ CDM}$	UNFCCC (2021f) as of 30 April 2021.
$V_{retirement\ Annex\ B}$	IGES (2020a, b) as of 7 August 2020, EU and Switzerland 30 April 2018, Japan 31 January 2021, New Zealand 10 May 2021.
$V_{cancellation\ Annex\ B}$	IGES (2020a, b) as of 7 August 2020, EU and Switzerland 30 April 2018, Japan 31 January 2021, New Zealand 10 May 2021, UNFCCC (2021f) for administrative cancellations as per 30 April 2021.
$V_{holding\ CDM}$	UNFCCC (2021d) as of 30 April 2021.
$V_{holding\ Annex\ B}$	UNFCCC (2021a) as of 31 December 2020; National registry websites or communications, e.g., EU and Switzerland (30 April 2018), Australia (as per 30 October 2020), Japan as per 31 January 2021), Project level carry-over data provided confidentially by Japan.

Source: authors.

The use of mixed cut-off dates in the dataset naturally diminishes the accuracy of the results, especially the lack of data from the EU transaction log after April 2018, given the large role of EU-based entities in CER transactions. This reduces the robustness of our analysis of unused CERs from activities registered since 2016. We try to estimate the numerical impact by cross-checking the EU registry with the EU's SEF information. The main form of 'use' of activities registered after 2013 and particular since 2016 is voluntary cancellation, and the EU registry is the place where most voluntary cancellations occur. Until April 2018, 85.4 million CERs were voluntarily cancelled in the EU registry, which amounts to 46.2% of all voluntary cancellations we have disaggregated data on. From the more recent SEF reporting of the EU, we know that we are omitting up to 14 million CERs voluntarily cancelled, all of them but a negligible amount (25,000 CP1 CERs) being CP2 CERs. These voluntary cancellations in the EU registry would increase the amount of voluntary cancellation in general from 185 million CERs to 199 million CERs (a 7.6% increase). We expect a similar tendency in the case of the Swiss registry, although transaction amounts are smaller. We therefore consider our results to be *overly conservative* regarding the unused CERs from more recent project activities registered since 2013.

At project level, we assess characteristics that are expected to be most relevant for ongoing negotiations in finding a compromise for transition of units to the post-2020 period. These characteristics are illustrated in Table 4:

Table 4: Definition of project characteristics for analysis of unused CERs

CER characteristic	Description
Host country	Refers to the place of origin of CERs.
Type of project	Refers to the project classification by UNEP DTU (2020).
Scale of project	Refers to large- or small-scale projects according to UNFCCC (2021e).
Registration date	Refers to the date of the decision of approval through the CDM EB according to UNFCCC (2011).

Source: authors.

Project-level information is identified through CER-unique serial numbers, reported individually or in block format, which include the original Project IDs that activities under the CDM are granted upon registration (Box 4).

Box 4: Identification of CERs through unique serial numbers

As per decision 3/CMP.1, the general rules for serial numbers of Kyoto units apply (section 2.5). The serial number is key to ensure that CERs are only held in one account in one registry at a given time, as required per decision 3/CMP.1, Appendix D, paragraph 4. The ITL needs these serial numbers to validate transactions and has specified the coding in its data exchange standard (UNFCCC 2013). In an ITL transaction, the number of CERs transacted is recorded by indicating both the Unit Serial Block start number and end number. While CERs should be identifiable throughout the entire transaction cycle by their unique identifiers, this is not always the case in national reporting due to reasons of confidentiality. Also, the CDM registry and the Adaptation Fund do not report serial numbers of their holdings (see section 4.1).

Display order	Identifier	Code
1	Host country	Two-letter country code
2	Unit type:	5: CER
3	Unit Serial Block Number	Max 15 digit value assigned by registry, 1-999,999,999,999,999
4	Original Commitment Period	2 digit, 1-99
5	Applicable Commitment Period	2 digit, 1-99
6	LULUCF activity	0 for CERs, coding only for lCERs and tCERs
7	Project identifier	Max 7 digit

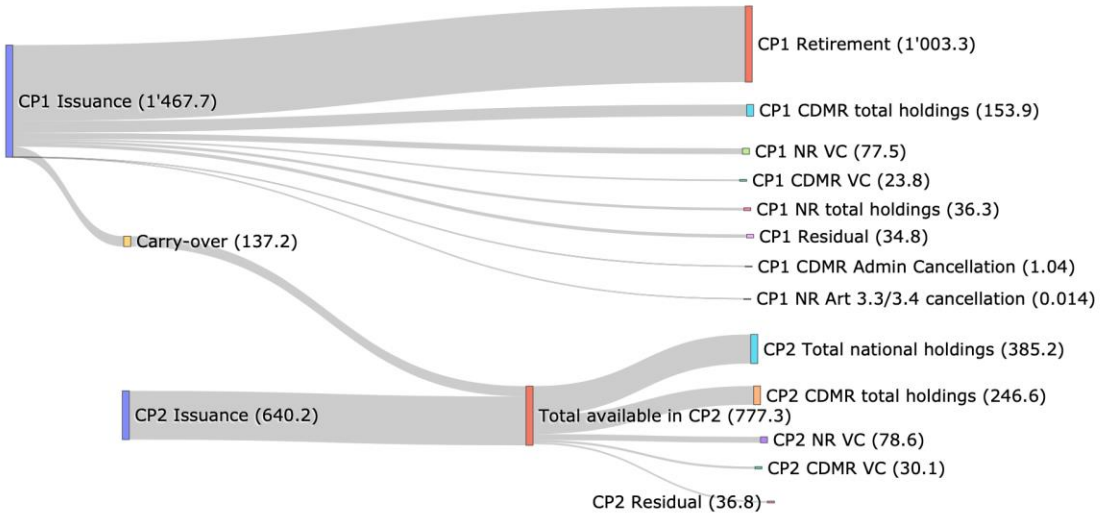
Source: UNFCCC (2013), p. F-2

3.2. Aggregate estimations of unused CERs

Following the stepwise procedure (Figure 8), the 'backward induction approach' leads to holdings of unused CERs in either national registries of Annex B countries or the CDM registry as well as a 'residual' for both CP1 CERs and CP2 CERs. This residual is further discussed in this section. Both holdings and transactions of CERs are illustrated by CP and include carry-over CERs in the form of a Sankey diagram (Figure 10).

The sum of issued CERs over CP1 and CP2 amounts to 2108 million, as of the cut-off April 30st, 2021. Of this total, the large majority (1707 million) has been forwarded to national registry accounts of governments ('party holding accounts) or companies ('entity holding accounts') via the ITL. The majority thereof (1003 million) retired by 2015, and a small fraction has been voluntarily cancelled. About 401 million CERs are currently held in CDM registry accounts, i.e., have not yet been forwarded and are therefore potentially available for first purchase (UNFCCC 2021d).

Figure 10: Aggregate overview on holdings and transactions of CP1 and CP2 CERs



Source: Authors, based on Betz et al. (2021). Note: VC stands for voluntary cancellation. Residuals in CP1 and CP2 result from the difference between the sum of issued CERs and sum of CERs used in each period and cannot be explained with available data.

As described in section 3.1, the stock of unused CERs can be calculated either by subtracting the total volume of used (retired and cancelled) CERs from the volume of total issued CERs or by summing up all CERs currently held in either national registries of Annex B countries or the CDM registry (Table 5). Comparing this outcome to the sum of national registry holdings by Annex B Parties and CDM registry holdings, it becomes evident that the balance equation to estimate the volume of available CERs (Equation 1) does not hold true, for reasons discussed below in this section.

By applying the 'backward induction approach', we estimate a stock of both CP1 and CP2 CERs of about 894 million CERs, which includes 822 million CERs of total holdings and a residual of about 72 million CERs. Including this residual, this corresponds to 42.4% of all units issued by the end of the cut-off date. Holdings in the pending or holdings accounts of the CDM registry of 401 million CERs correspond to about 19% of all CERs issued to date. On the other hand, national registries in Annex B countries report in their SEF tables aggregate holdings at the end of 2020 of currently 422 million CERs, or about 20% of all CERs issued to date. The combined holdings of CERs amount to some 39% of all CERs issued by the end of the cut-off date. The calculated residual of about 35 million CERs in CP1

(37 million CERs in CP2) is the difference between estimating unused CERs with the backward induction approach versus estimating unused CERs through summing total holdings in the CDM and national registries. This residual cannot be counted at face value as 'unused' and 'available' for a potential transition. Rather, it illustrates the lacking traceability of Kyoto units in the current reporting system.

Table 5: Differences of estimating the amount of unused CERs (in millions)

	'Backward induction approach' (Issuance – Use)	Sum of holdings (CDMR plus national registries)	*"Residual"*
Commitment period 1	224.9	190.2	34.7
Commitment period 2	668.6	631.8	36.8
Total	893.5	822.0	71.5

Source: authors, based on Betz et al. (2021).

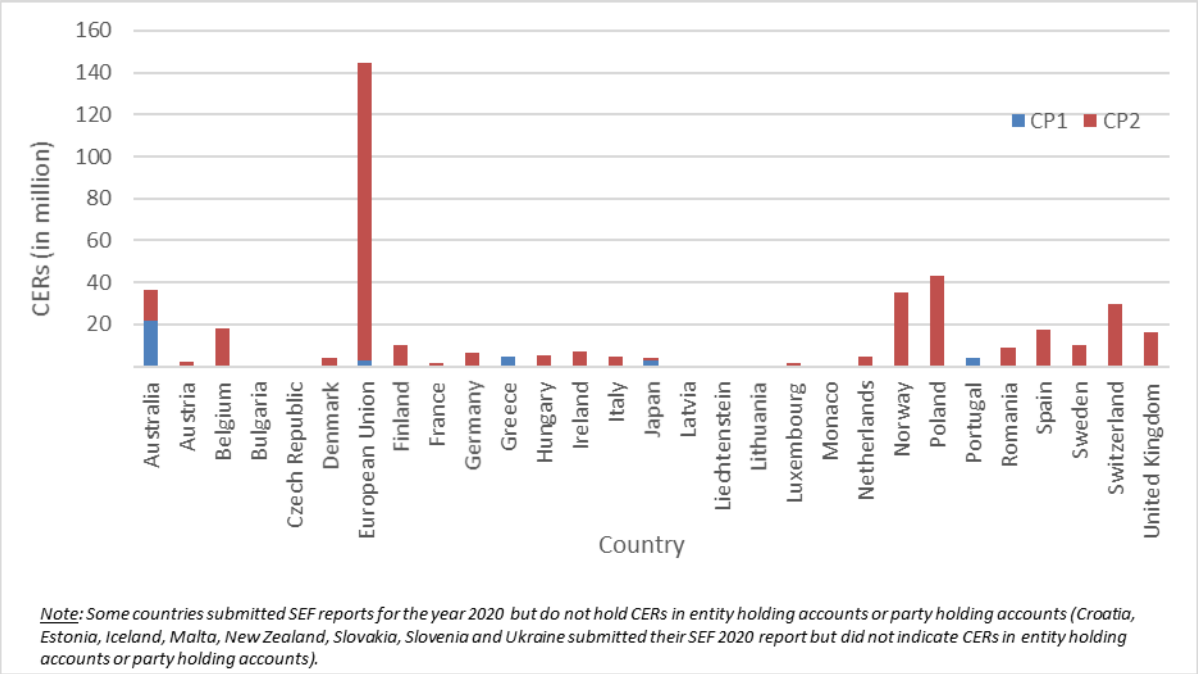
We assume in the following that the 'residual' corresponds to unreported holdings in national registries, as we have confirmed CDM holdings with the UNFCCC Secretariat.

The CDM registry does not disclose how many CERs are contained in holding accounts, and how many in the pending account. In its regular reporting, distinction is only made between CP1 holdings (154 million in its latest report) and CP2 holdings (247 million). These are CERs that potentially have not found any buyer so far. A transition of these CERs is in the interest of the project developers or the trustee of the Adaptation Fund, the World Bank, which has received CERs as in-kind share of proceeds for adaptation and has the statutory task of monetizing them under the best possible conditions.

The aggregate holdings of the Adaptation Fund are known from the annual Trustee reports (the most recent is World Bank (2020)) and amount to 10.3 million CERs. By subtracting the aggregate amount held by the Adaptation Fund from the total CDM registry holdings, we calculate 391 million CERs that are in the pending account or held by project participants. For these CERs, we would assume a transition to be in the interest of the project developer, as this would allow marketing CERs in the international carbon markets under the PA.

The distribution of ownership of the total of 422 million CP1 and CP2 CERs among Annex B Parties is illustrated in Figure 11.

Figure 11: CERs reported in Entity and Party holding accounts in CP1 and CP2



Note: Some countries submitted SEF reports for the year 2020 but do not hold CERs in entity holding accounts or party holding accounts (Croatia, Estonia, Iceland, Malta, New Zealand, Slovakia, Slovenia and Ukraine submitted their SEF 2020 report but did not indicate CERs in entity holding accounts or party holding accounts).

Source: authors, based on Betz et al. (2021).

While about 185 million CP1 CERs were requested to be carried over to CP2 in national registries, 137 million CERs have reportedly concluded the carry-over transaction (IGES 2020b). This corresponds to 9.3% of CP1 issuance. For these CERs, it can be assumed that a payment to the project owner has taken place, as otherwise they would not have been transferred from the CDM registry to a government registry of an Annex-B country. This assumption is particularly salient given the early and persistent dominance of 'unilateral' CDM projects developed by host country actors without involvement of an Annex B investor (for a discussion, see Lütken and Michaelowa 2008). It should be noted that Parties have not yet completed their carry-over processes from CP1 to CP2 (see section 2.5), and data differs on reported carry-over and documentation publicly available on requested carry-overs.

Annex B registries currently still hold CP1 CERs that have not been carried over. These 36 million CERs, or 2.5% of CP1 issuance, are 'zombie' CERs and could be deducted from the total available CERs. CP2 CERs held in Annex B registries and not carried over (up to a quantitative limit of 2.5% of the Annex-B Parties assigned amount) or 'converted' into PA eligible units could also become such 'zombies' in the future. However, as discussed below, this requires the expropriation of private entity CER holders.

CP1 and CP2 CERs in the CDM registry are exempt from mandatory cancellation and available if not otherwise cancelled.

Based on the aggregate-level analysis, we consider:

- 154 million CP1 CERs to be still available (13% of total CP1 issuance) as they are still in the CDM registry. A further 36 million holdings of CP1 CERs in national registries should be mandatorily cancelled as per CMP decisions, which is why we consider them to be 'zombie' units.
- 35 million CP1 CERs as 'residual', i.e., units whose whereabouts could not be attributed in the dataset (2.4% of total CP1 issuance).
- 632 million CP2 CERs available, of which 247 million CERs are in the CDM Registry and 385 million CERs in holding accounts of national registries, including eligible CP1 CERs that were carried over.
- 37 million CP2 CERs as 'residual', i.e., units whose whereabouts cannot be attributed (4.7% of total CP2 available units, i.e., CP2 issuance plus carry-over).

Thus, we calculate a total of **822 million unused CERs**, with the large majority of those (77%) being CP2 units, and a **remaining unexplained total residual of more than 71 million CERs** in our dataset consisting to similar proportions of CP1 and CP2 units**.** The residual could only be attributed based on ITL information. Of these 822 million unused CERs, we estimate only **786 million CERs to be available for transition**, excluding the 'zombie' CERs.

3.3. Characteristics of unused CERs according to project type

Before analyzing the project type-specific analysis undertaken, we would like to discuss the challenges and limitations of this analysis encountered, primarily due to highly varying interpretations of the reporting requirements by national registry administrators and the lack of granular information published by the CDM registry. There is a lack of a central entity with the authority to disclose project-level unit data to the public, according to common rules and guidelines. The ITL comes closest to fulfilling this role of accountancy, but its mandate limits its capacity to disclose such information. Only highly aggregated data are accessible on an annual basis from the ITL, and its latest report covers only the period up to 30 September 2018 (UNFCCC 2018); there is thus a data gap of three years. This substantively hampers comparability and resulted in major challenges for the study team to assess both the whereabouts and the characteristics of currently available CERs. As we had to separately ask for data from national registries, the data obtained was anonymized and partly aggregated, in addition to being from different timescales. This also leads to differences for the aggregated CER volumes compared to the top-down analysis undertaken in the preceding section.

The bottom-up estimate of unused CERs is close to 955 million, compared to 894 million from the top-down analysis. This number is likely to be overestimated as Parties continue to engage in transactions, notably cancellations, after the latest date's data was made available to us. As most data at our disposal does not differentiate CP1 and CP2 units, we could not exclude the 'zombie' CERs from the stock of available CERs in the disaggregated analysis. In addition, we do not have disaggregated data on the voluntary cancellations in the EU registry since April 2018, which is where most voluntary cancellations

– the main type of use associated with CP2 CERs— occurs. As shown above, the aggregated volume of such post-2018 cancellation in the EU registry reaches about 14 million CERs.

In conclusion, our analysis is likely to ***overestimate*** available unused CERs, which we deem positive as it is a more conservative estimate. It is important to emphasize that we do not estimate total future availability, as further issuances for ongoing projects will be requested. A final analysis can only be undertaken based on ITL data.

A summary of the difference in estimates of unused CERs using the backward induction approach in the aggregate and project-level analysis is provided in Table 6 below.

Table 6: Summary of estimates of unused CERs by approach (in millions)

	Aggregate analysis	Project-level analysis
Unused CERs (backward induction approach)	893.5	954.9
Aggregate level reporting to the UNFCCC	823	823
Difference backward induction – Party reporting	**+70,5**	**+131,9**

Source: authors, based on Betz et al. (2021).

Our project-level analysis shows a higher amount of unused CERs than the aggregate analysis, most likely because we did not have access to most recent information on holdings and voluntary cancellations undertaken in national registries, while we do have recent information on issuances in the CDM registry. In our view, aggregate information on holdings cannot be directly translated into amounts of CERs available for eligibility in post-2020 carbon markets, as part of the holdings should be subject to mandatory cancellation as per CMP rules. The difficulty in obtaining project-level information on both used and unused units in the absence of a central accounting entity underlines the importance of reconsidering such procedures under the Paris Agreement mechanisms and enhancing overall transparency, whilst safeguarding the confidentiality of activity participants to a sufficient extent.

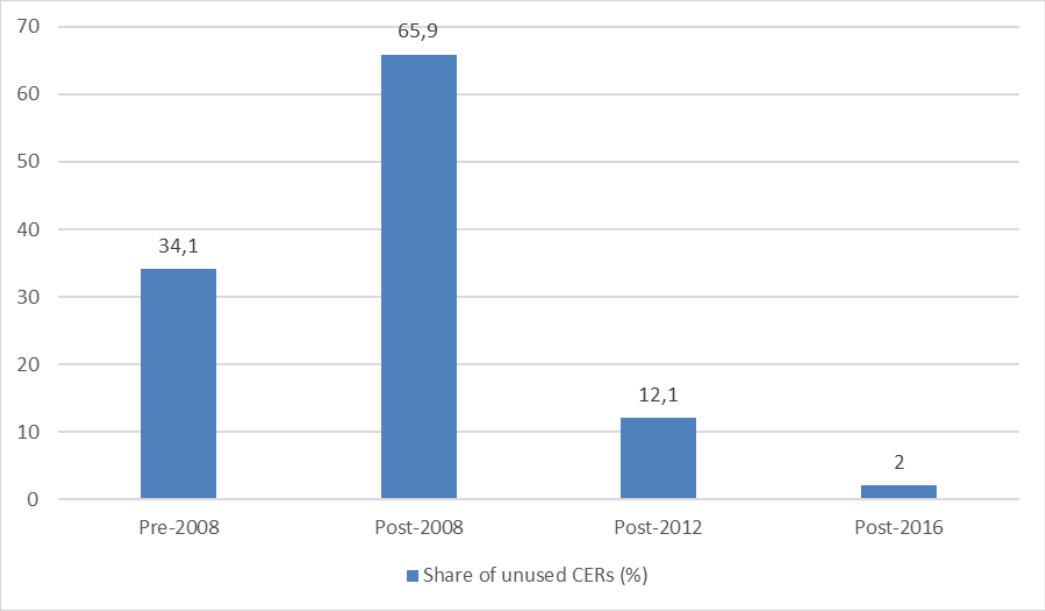
3.3.1. Quantitative impact of registration-based cut-offs on unused CERs

In a first step, we analyze the implications of distinguishing the unused CERs by the registration dates of the underlying projects. At COP25 in Madrid, Article 6 negotiators discussed potential options to allow for a restricted eligibility of CERs in post-2020 carbon markets that come from project activities:

- Registered under the CDM (no cut-off date). This includes CDM activities registered since 26 June 2005;
- Registered as of 1 January 2008, which corresponds to the start of CP1;
- Registered as of 1 January 2013, which corresponds to the start of CP2; and
- Registered as of 1 January 2016, which is understood to be the ‘early action’ period following the adoption of the Paris Agreement.

Note that from all unused CERs (955 million), 330 million are from projects registered pre-2008 (330 million CERs). This means that a significant share of these very early project activities was not sold and used on the international carbon market. This is due to early-mover project types with high CER issuance streams, such as industrial gas projects, which have had difficulty selling CERs after attacks by NGOs for lack of environmental integrity and being made ineligible for use by private entities in the context of national ETSs by Annex B countries (see subsequent section). 630 million CERs are from projects registered from 2008 onwards, 115 million from 2013 onwards and just 19 million from 2016. Figure 12 shows the shares for these four periods.

Figure 12: Shares of unused CERs according to registration date cut-off of CDM activities



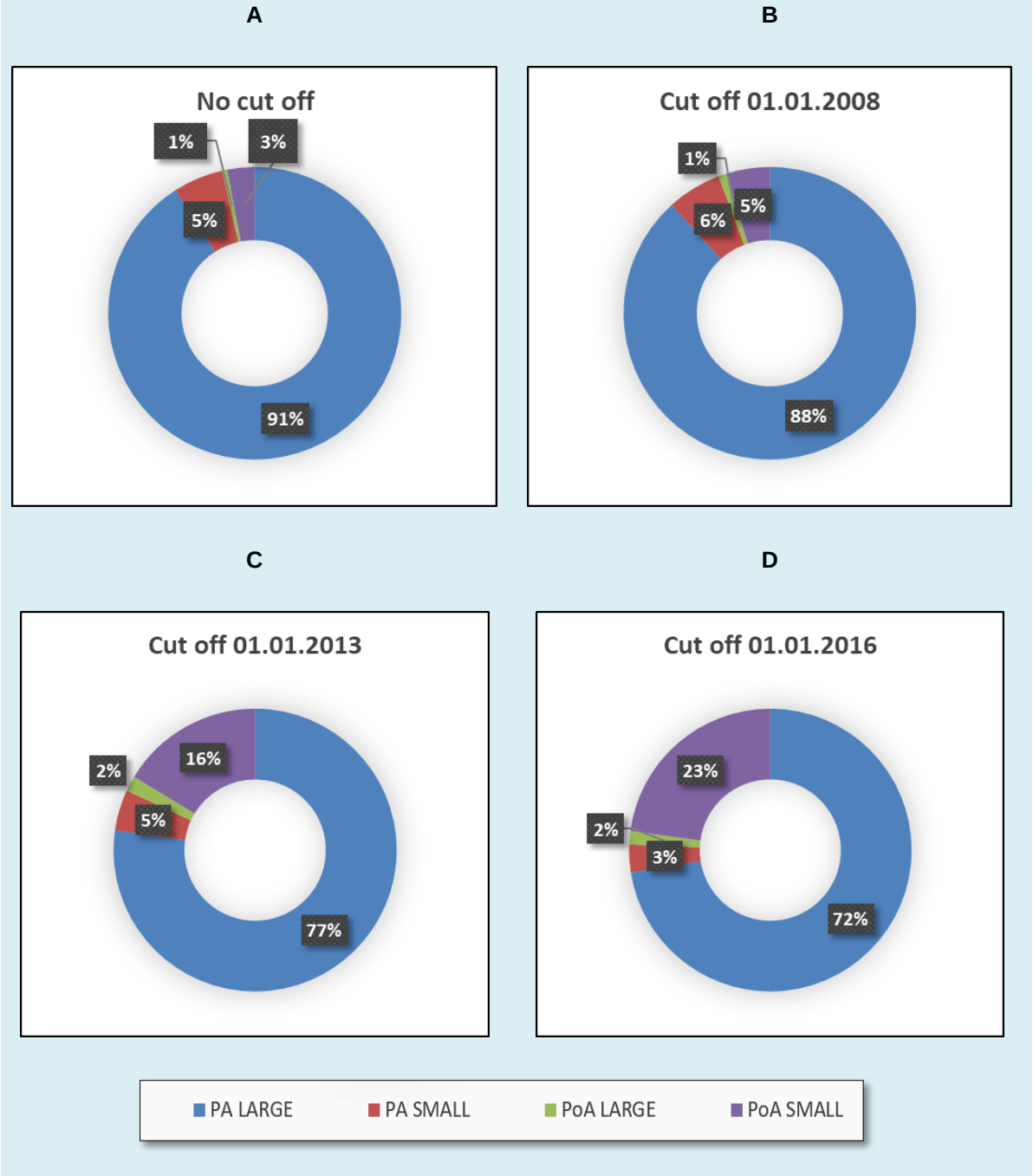
Source: authors, based on Betz et al. (2021).

The highly skewed nature of the registration dates of projects with unused CERs is mirrored by the overarching developments of demand and supply in the KP era (see section 2.2), as registration numbers soared as demand picked up, but issuance often only occurred after prices crashed. At the same time, it must be noted that recently registered activities are more likely to deliver potential future issuances for mitigation achieved since 2012 or 2016 respectively, as crediting periods under the CDM are 7 years (renewable twice, amounting to 14 years) or 10 years (non-renewable).

3.3.2. Impact of registration dates on activity scales and types

We now assess the scale and type of the unused CERs, the project status of the activity, the main host countries of the activities and the main project types of the unused CERs for the different registration cut-offs. It is not possible to directly compare the following analysis with the aggregate level analysis, as we cannot differentiate between CP1 and CP2 units, because this information was not made available to us at a disaggregated level. Figure 13 shows us that while unused CERs from large-scale project activities dominate unused CERs across all cut-off dates, their share is reduced favouring small programmes of activities the later the cut-off date is set, especially since 2016.

Figure 13: Scale (large or small) and project vs PoA share by different activity registration dates



Source: authors, based on Betz et al. (2021). Note: PA- Project activity; PoA - Programme of activities.

As Figure 14 shows, hydro activities are the largest activity type across all registration date thresholds with 169 million unused CERs in total, 152 million from 2008, 33 million from 2013 and 4 million from 2016. The vast majority of all CERs of this type issued stem from large scale projects (88% of all hydro issuances), as does the vast majority of the unused hydro CERs (90%). The share of unused hydro CERs is slightly higher than the hydro share in all issued CERs. In total, 53% of all issued hydro CERs remain unused to date. This shows that project developers have suffered significantly from the downturn of the CER market. However, given that hydropower projects have an ongoing revenue stream from electricity sales and are often operated by public entities that do not have fully commercial

incentives to optimize revenues, the pressure for transition of hydro CERs may be less than if the sector was dominated by private enterprise.

The second most important source of unused CERs are wind projects, with 17.8% of unused CERs, almost all of which (97%) come from large projects, much higher than their share of 13.1% of all CERs issued. The share of these projects falls massively the later the registration cut-off: for a 2008 cut-off, wind projects represent 25% of the unused CERs, for 2013, 19% and for 2016, just 0.2% (from two projects). In total, 61.2% of all issued wind CERs remain unused to date. Given wind projects have ongoing revenues from electricity sales, their pressure may be less than the share of unused CERs would suggest.

The third largest project type is N_2O abatement, with 132 million unused CERs, 13.9% of the total. This project type would suffer massively from later registration cut-offs as only 16 million unused CERs come from projects registered from 2008 onwards (0.9 million from 2013 and none from 2016). In total, 36.6% of all issued N_2O CERs remain unused to date, much lower than the average across all project types, but still significant. Given that N_2O project developers, especially in the context of nitric acid production, have incurred significant operational abatement costs without revenues, they may be the most heavily affected category of all project developers and therefore heavily lobby for transition. The few adipic acid producers which have made good revenues in the CDM 'gold rush' period may be able to write off the remaining unused CERs from their projects.

Projects for destruction of HFC, mainly of HFC-23 in HCFC-22 waste streams, cover 11.2% of all unused CERs, with 107 million CERs. CERs from HFC-23 abatement projects became a de facto unsellable commodity after 2012[15]. Like N_2O reduction, this project type would suffer massively from later registration cut-offs as only 26 million unused CERs come from projects registered from 2008 onwards, and none from 2013 and 2016. However, in total, only 19.8% of all issued HFC CERs remain unused to date, which shows that most activity developers were able to sell the bulk of issued CERs and stopped issuance when HFC CERs became unsellable. The losses for project developers thus are rather limited.

The above-described activity types make up 71.1% of all issued CERs and 60.5% of all unused CERs. Any cut-off date lowers their cumulative relevance in the eligible portfolio. Their share among unused CERs falls to 58% from activities registered since 2008, 47% with a 2013 cut-off date and 49% for activities registered since 2016.

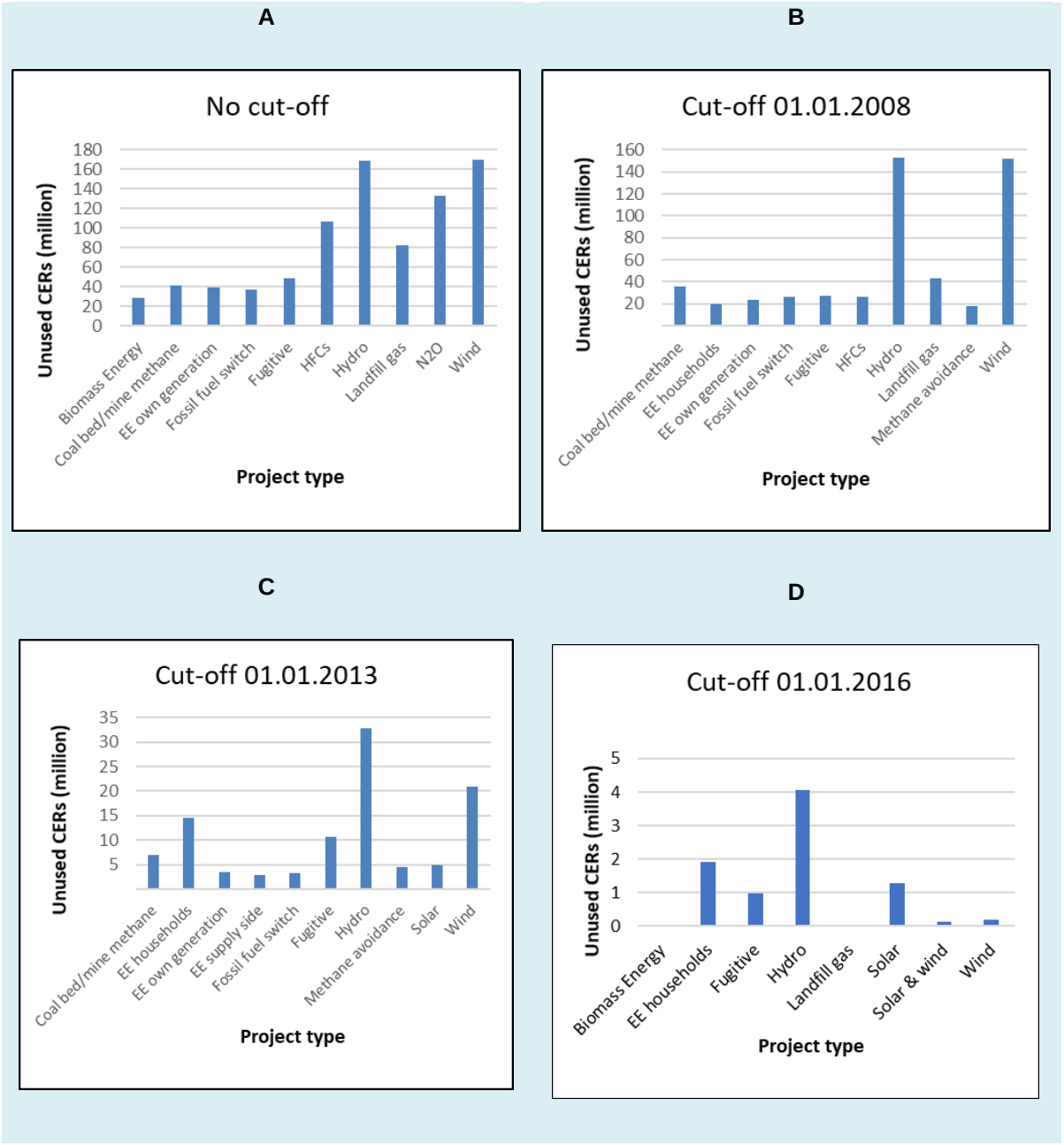
We now look at project types whose share in unused CERs rises the later the cut-off date is set: activities that relate to energy efficiency in households— mostly cookstoves and efficient lighting and solar energy. These are mostly small-scale programmes of activities (making up 91% of all issued CERs from this project type). While CERs from EE in households only represent 1.1% of all CERs issued and 2.1% of all unused CERs, the share of unused CERs increases to 3.4% from 2008, 12.6%

[15] Please see a detailed discussion of the history of HFC-23 abatement in the CDM and its unlikely continued eligibility in PA market schemes, given that the Montreal Protocol now mandates this type of mitigation activity, in Michaelowa et al. (2018).

from 2013 and 22% from 2016. With 89% of CERs from this activity type remaining unused, an absence of eligibility provisions for post-2020 carbon markets would heavily impact activity developers. However, the share of unused CERs falls over time – for activities registered since 2016 it reaches 77%.

For solar energy, the effect is even more pronounced: their share of unused CERs increases from 1.7% of unused CERs from 2008 to 3.5% from 2013 and 16% from 2016. For the latter period, almost all solar CERs belong to large-scale solar activities. We would like to note that under the CDM, recently more large-scale solar energy projects have been registered, while additionality of these activities becomes more and more questionable. Gold Standard (2019) and Verra (2019) have now adopted rules that exclude most grid-connected solar activities from registration in their standards.

Figure 14: Top 10 project types of the unused CERs by activity registration dates



Source: authors, based on Betz et al. (2021). Note: EE - Energy efficiency; HFCs – Hydrofluorocarbons; N2O - Nitrous oxide. See UNEP DTU (2020) for exact descriptions of project types. With cut-off date after 2016, only eight project types were left. Note the strong variation of the y-axis scale (amount of CERs) when comparing the figures. Please also note that different project types dominate the portfolio with a different registration cut-off date. The total amount of unused CERs from the selected top 10 project types exceed 80% of unused CERs from all project types.

On average, 55% of all issued CERs were sold. Comparing the share of unused CERs to the share of issued CERs from a specific project type (Figure 15), some project types have performed below average. Activity participants that invested in abatement of fugitive emissions in the oil and gas sector[16], in particular in Qatar, Uzbekistan, Bangladesh and Vietnam, were unable to sell a large share of their issued CERs and 85% of issued CERs remain unused. 67% of coal bed or mine methane activities[17], located almost exclusively in China with exception of one in Mexico, remain unused.

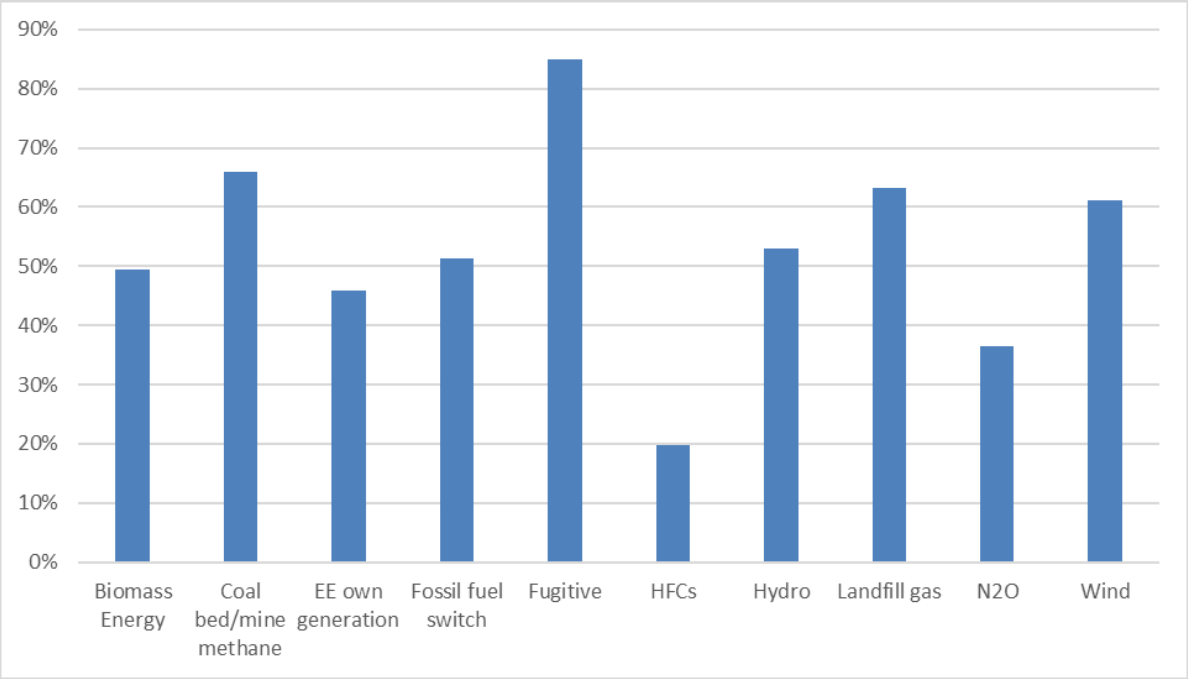
Landfill gas activity developers were also less able to sell their CERs than average with 63% of CERs unused. 166 landfill gas activities still have unused CERs in the dataset, 47% of all unused CERs from LFG activities are in Brazil, another 20% in other LAC host countries, 10% in China and a further 18% in other Asian countries, the remaining 5% stemming from activities in Africa (Betz et al., 2021). LFG was a dominant category of the early years of the CDM and an activity type with long crediting periods. A 2008 registration-based cut-off already limits eligibility to 52% of the unused CERs. A 2013 cut-off date reduces the eligible unused CERs from this category to just 2%.

Wind projects also performed worse than average. Surprisingly, activities in the industry sector, in particular energy efficiency own generation (which relates inter alia to cement heat projects, cook oven gas, iron & steel heat and chemicals heat activities) performed better than average. It can be assumed that large and well-organised industrial actors with an interest in the market had a higher sales success. Fossil fuel switch activities have also performed better than average, which relates mostly to natural gas activities. 50% of all remaining CERs of this project type stem from activities in China and 44% from activities in India.

Biomass activities, with 268 activities with CER issuances, also performed above average. 30% of unused CERs from these activities stem from activities in China, a further 29% from activities in India and 12% from activities in Brazil. Among the largest activities with unused CERs are also activities in Chile and Malaysia.

[16] Sub-types of the category 'fugitive' include oil field flaring reduction (8 activities with issuances), oil and gas processing flaring (2 activities with issuances), natural gas pipelines (6 activities with issuances) and to a lesser degree charcoal production (2 activities with issuances) and non-hydrocarbon mining (1 activity with issuance).
[17] These activities include the capture and destruction and/or use of coal bed or mine methane, coal mine methane or ventilation air methane from new, existing or abandoned coal mines.

Figure 15: Share of unused CERs in total CERs issued (by %) according to activity type

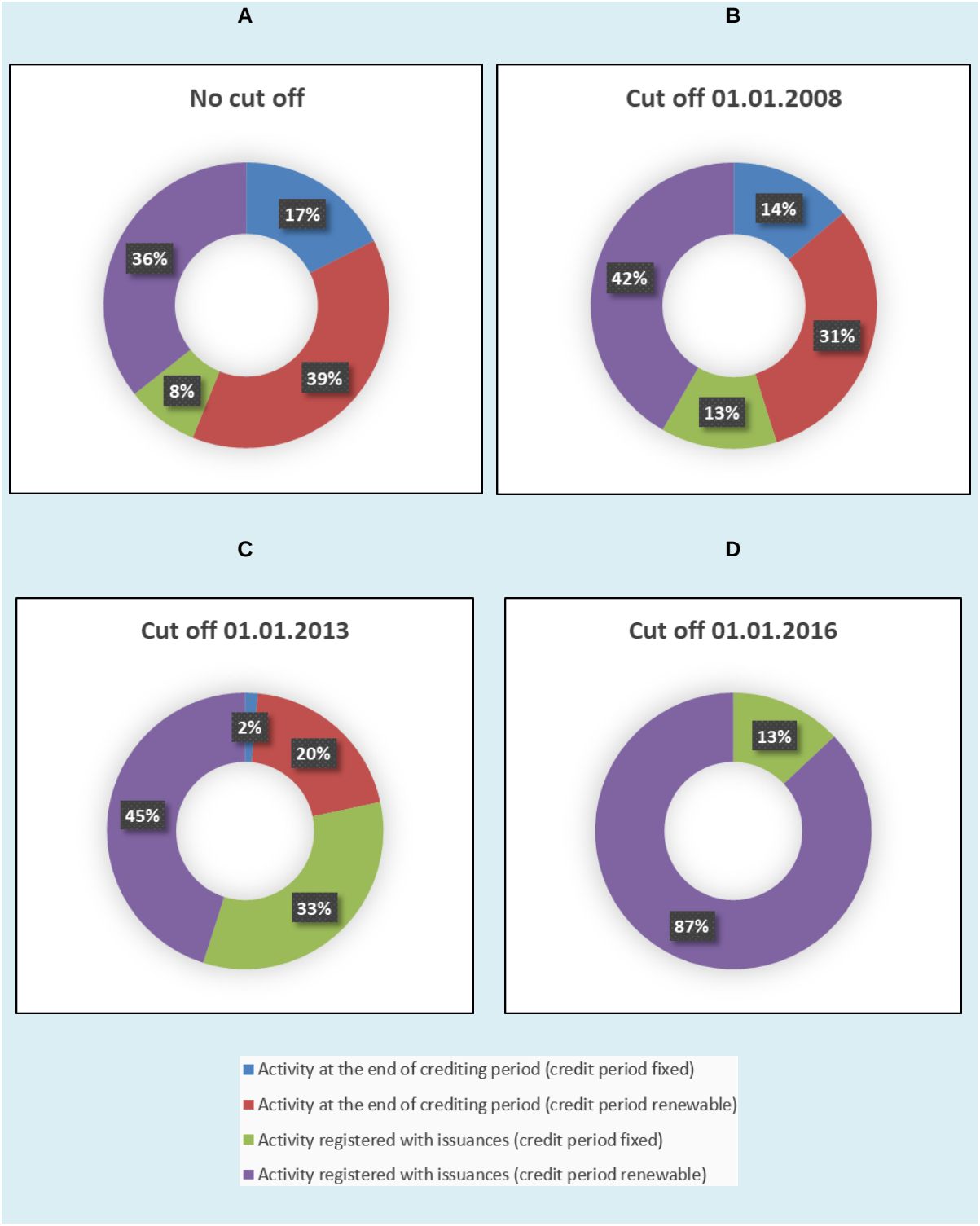


Source: authors, based on Betz et al. (2021).

3.3.3. Impact of registration dates on activities supported

Unsurprisingly, the later the cut-off date is set, the more it favours ongoing CDM activities compared to those that have reached the end of their crediting period. A cut-off date in 2016 would mean that 87% of CERs would come from ongoing activities with a renewable crediting period. In the absence of a cut-off date, 56% of all unused CERs come from finalized activities.

Figure 16: Project status of activities from unused CERs by different activity registration dates



Source: authors, based on Betz et al. (2021).

3.3.4. Impact of registration dates on host countries

A closer look at host countries' interests in transition can explain their preferences in the negotiations. First, we focus on Brazil, China, and India as major CDM host countries and advocates of unlimited CER transition.

China is associated with 45.3% of all unused CERs issued, totalling 432 million. Of the three frontrunners, China has been able to sell the highest share, leading to 61% of CERs having been retired or cancelled. Surprisingly, a 2008 cut-off date generates a limited loss of only 95 million CERs compared to a situation where all CERs would be rendered eligible for PA carbon markets. The situation changes for later cut-off dates, as the Chinese share of unused CERs declines to 30% of unused CERs from 2013 and an exclusion of 303 million CERs from eligibility. A 2016 cut-off would lead to the exclusion of all 432 million Chinese CERs from NDC compliance markets, as there is only one (large-scale energy efficiency supply side) CDM project registered in China after 2016 in the database (Betz et al. 2021), which has not yet resulted in any issuance.

Generally, Chinese sales have taken place early; the share of used CERs falls to 45% from 2008 and 4% from 2013. Project developers active in China have a clear interest in advocating for a cut-off date no later than 2008 in allowing for the use of CERs in post-2020 carbon markets, as they lose massively with later cut-off dates.

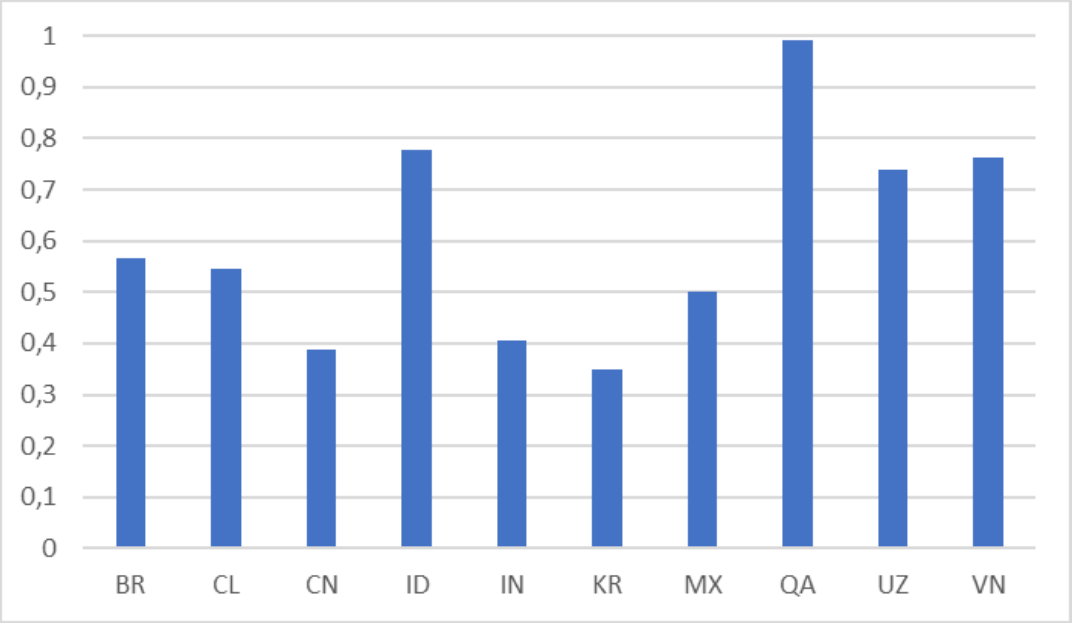
India is associated with 11.2% of all unused CERs, totalling 107 million CERs. With a cut-off for project registration in 2008, already 55 million unused CERs would be barred from post-2020 compliance markets. When applying a 2013 cut-off, the additional loss remains limited to 39 million. A cut-off for activities set in 2016 still leaves roughly a million CERs eligible in a post-2020 period. In contrast to China, India's relative importance as a host country thus remains relatively stable irrespective of the cut-off dates chosen. Indian project developers have been active more consistently even during the 'doldrums' of the CDM market; of the CERs from projects registered since 2013, 25% were retired or cancelled (a much higher share than in China) and 18% of all CERs issued from India's activities registered since 2016 are no longer available for use. From a market balance point of view, programme developers active in India would thus be less affected than those active in China from later cut-off dates.

Brazil is comparable with India, totalling 89 million unused CERs. Compared to the issuance of CERs for activities in Brazil, they have a higher share of unused CERs than China and India, as only 43% of Brazilian CERs have been used. This explains Brazil's vehement opposition to limiting CER carry-over. A cut-off date in 2008 already leads to the exclusion of 57 million CERs, more than in India. The shift to the 2013 cut-off date eliminates another 24 million CERs, a relatively benign restriction. A project registration cut-off date of 2016 renders 0.13 million CERs eligible for NDC use, all of which belong to one large-scale solar and wind project registered in 2016. Brazil thus has an interest in arguing for full transition, much more than China and India.

In sum, all three governments of the leading CDM countries – if they want to support project developers active in their jurisdiction – have a clear interest to advocate for earlier cut-off dates as they have a lower share in more recent activities, when participation in the mechanism diversified. In turn, this means that host countries other than the historically most active host countries 'benefit' from a late cut-off.

We now look at the overall success rate of CER sales for all countries (see Figure 17), which reaches 45% globally. The higher the share of unused CERs in total issuance, the lower the success in selling CERs on the global carbon market. Here, less prominent host countries dominate, in particular Qatar, Uzbekistan, Vietnam and Indonesia. In Qatar, all unused CERs stem from one large-scale oil field flaring emission reduction project, registered in 2007, where 14.5 million CERs were issued so far. Uzbekistan saw registration of activities between 2009 and 2011, with six N_2O abatement projects, four activities on abating fugitive emissions from natural gas pipelines and one landfill gas project. Vietnam was and remains an active CDM host country with activities registered between 2005 and 2019 on a broad range of types, with a clear domination of hydro projects (59 in total), which also represent 50% of the share of unused CERs from this country. A further 28% is related to one activity on oil field flaring. Like Vietnam, Indonesia was active for many years, between 2006 and 2015, with a diversified portfolio. They also have one large-scale fugitive emissions activity, as well as one fossil fuel switch activity in the context of natural gas, but these have only a negligible share among the unused CERs (2.2% in total). Over 80% of unused CERs from activities in Indonesia stem from geothermal activities (35%), one cement activity (25%) and eight hydro activities (23%).

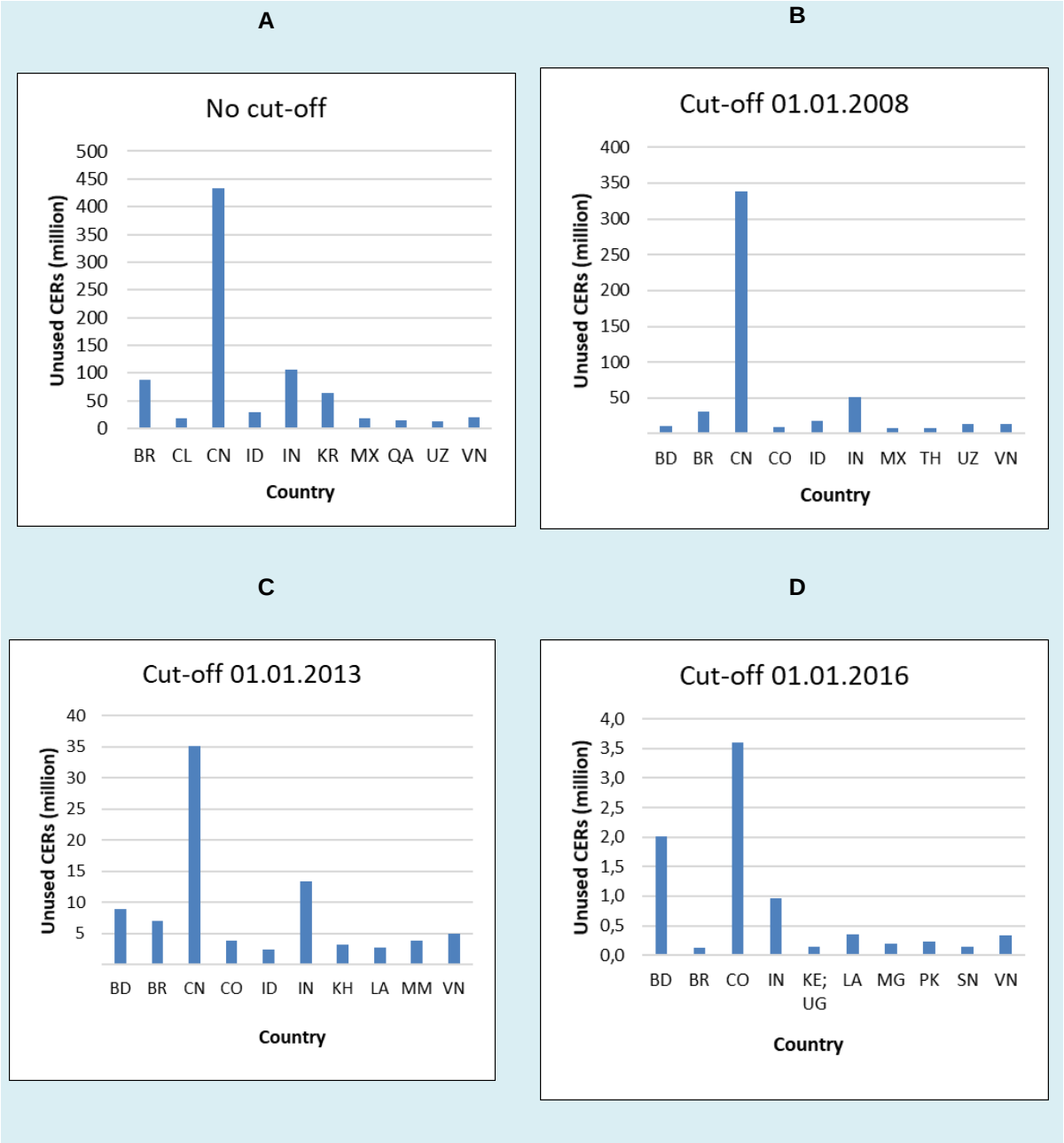
Figure 17: Share of unused CERs in total CERs issuances by Top 10 host countries



Source: authors, based on Betz et al. (2021). Note: BR - Brazil; CL - Chile; CN -China; ID - Indonesia; IN - India; KR - Republic of Korea; MX - Mexico; QA - Qatar; UZ - Uzbekistan; VN - Viet Nam. The Top 10 host countries were selected according to the total sum of unused CERs from projects (rather than issuance).

An overview of all countries regarding the total volume of unused CERs and the volume for each of the cut-off dates is presented in Figure 18. We discuss the relative position of the various continents and key countries.

Figure 18: Main host countries of activities with unused CERs according to different activity registration dates

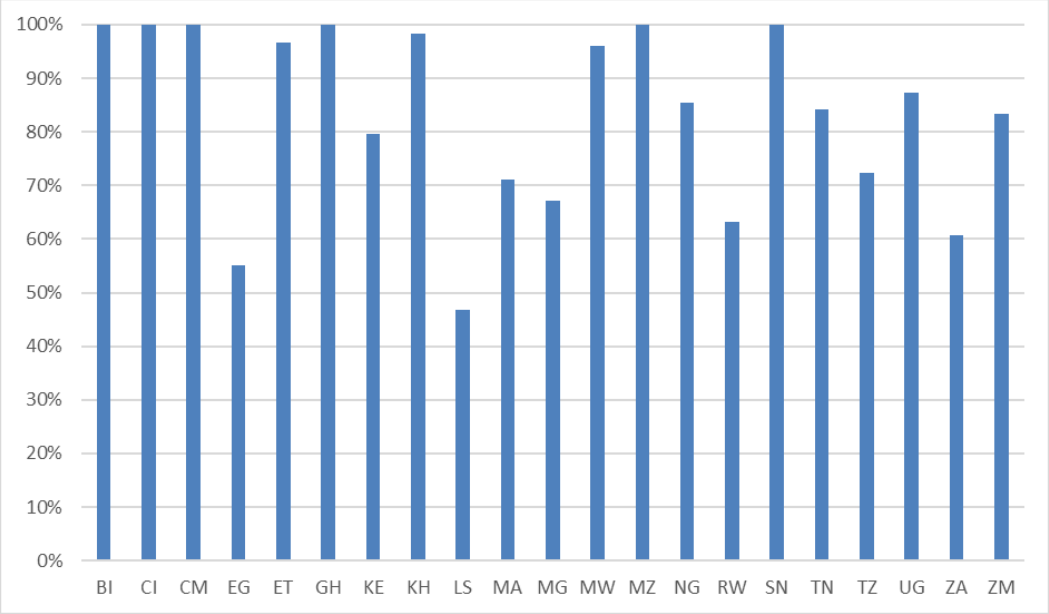


Source: authors, based on Betz et al. (2021). Note: BD - Bangladesh; BR - Brazil; CN -China; CL - Chile; CO - Colombia; ID - Indonesia; IN - India; KE - Kenya; KH - Cambodia; KR - Republic of Korea; LA - Lao PDR; MG - Madagascar; MM - Myanmar; MX - Mexico; PK - Pakistan; QA - Qatar; SN - Senegal; TH - Thailand; UG - Uganda; UZ - Uzbekistan; VN - Viet Nam. Projects can take place in multiple countries. The total amount of unused CERs from the selected top 10 host countries exceeds 80% of unused CERs from all host countries. Please again note the different scale of the vertical axis.

For host countries in Africa, which were latecomers and whose share in issued CERs remains at 3% only, 70% CERs issued so far remain unused. Shares of unused CERs in total CER issuance by host country are illustrated in Figure 19. This value reaches even 95% if the cut-off date is set at 2016; for this time countries in Africa has a share of 9% of global unused CERs. Here, the key host countries would be Kenya, Madagascar, Senegal, and Uganda. In general, activities in most African host countries were unable as of now to sell a significant share of their CER issuances, with notable exceptions in Egypt with a broader range of activities registered between 2006 and 2013, Lesotho (sold more than half of its CERs from one small-scale efficient cookstove project registered in 2012), Rwanda with two small scale EE households and one large scale solar activity, registered between 2010 and 2015 and South Africa with different issuances from activities registered between 2006 and 2016 .

This would mean that project developers active in African countries would have an interest to lobby for a 2016 cut-off. The African Group of negotiators rejecting the use of any pre-2020 units is thus not in line with project developers' interests active in the African region.

Figure 19: Share of unused CERs in total CERs issuances by African countries



Source: authors, based on Betz et al. (2021). Note: BI – Burundi; CI – Côte d`Ivoire; CM – Cameroon; EG – Egypt; ET – Ethiopia; GH – Ghana; KE – Kenya; KH – Cambodia; LS – Lesotho; MA – Morocco; MG – Madagascar; MW – Malawi; MZ – Mozambique; NG – Nigeria; RW – Rwanda; SN – Senegal; TN – Tunisia; TZ – Tanzania; UG – Uganda; ZA – South Africa; ZM – Zambia.

Asian host countries other than China and India have a share of 17.6% of all CER issuances, with 80% remaining unused. They thus have been relatively unsuccessful in selling CERs. If a 2016 cut-off date is set, these countries would benefit given that they have a share of 36% of all unused CERs in that period. Bangladesh, Laos, Pakistan, and Vietnam would benefit in terms of relative market share. These countries are part of the Like-Minded Developing Countries group which is supporting unlimited CER transition. We would expect that they would be more willing to compromise on a (later) registration threshold than the "heavyweights".

Latin American and Caribbean host countries other than Brazil cover 6.3% of CER issuances to date with 48.5% remaining unused, showing their early engagement and successful sales strategies. For the period from 2016, there is only one relevant CDM activity, a large-scale hydro project in Colombia that has issued 4.4 million CERs, representing 42% of all issuances from CDM activities registered since 2016 and where 82% remain unused, representing 42% of all unused CERs from activities registered in that time frame. We would however expect that these units are attractive for use under the Colombian carbon tax. There are a few further activities in Colombia registered since 2016 with no issuance to date. These are likely destined to deliver CERs for the domestic carbon tax scheme and a transition would make them eligible for domestic NDC achievement post-2020 if the government chooses so. We note that formally, Colombia as member state of AILAC and signatory to the San José Principles rejects the use of pre-2020 units towards NDCs.

Compared to the 'pro-rata'-approach by Lo Re and Vaidyula (2019)[18], the following table indicates the unused CERs by host country relative to all unused CERs for the top five countries of origin:

Table 7: Distribution of host countries regarding unused CERs (no cut-off date): A comparison with Lo Re and Vaidyula (2019)

All figures in %	China	India	Brazil	Korea	Mexico	Indonesia
Project-level analysis (this study)	45.3	11.9	9.2	6.7	1.9	3.1
'Pro-rata'-approach (Lo Re and Vaidyula (2019)	55.0	12.7	7.3	9.0	4.2	-

Note: Lo Re and Vaidyula (2019) identify Mexico as the fifth largest issuer (and according to the 'pro-rata' logic, therefore fifth largest country of origin for unused CERs) and not Indonesia. Next to different estimation approaches, the variation in outcomes can partially be explained by the use of more recent data.

3.4. Analysis of holdings

Due to data limitations, our analysis of characteristics of unused CERs is too conservative, but robust. In comparison, our analysis of the characteristics of holdings is less robust, due to the risk of double counting CERs that are still traded between registries, while having different cut-off data for holdings. E.g., if we count a CER as held in the EU registry in 2018, that CER may very well been transferred to the Australian registry, where we would count it as held as of 2020 in the data we have. In addition, we do not have disaggregated information on holdings from all registries (e.g., New Zealand). Given these limitations, we try to clearly explain the added value and limitations of our analysis where relevant. Still, we can assess the characteristics of CERs held in national registries at the point in time the respective data was made available to us. In total, we have detailed information on 339 million CERs in holding accounts, i.e., 80.3% of CERs reported by Annex B Parties in their registries as of 2020. These include 16.4 million CERs held in the Australian registry (corresponding to 4.8% of all holding volumes we have obtained), 17 million CERs held in the Swiss registry (corresponding to 5% of holding volumes), 302 million CERs held in the EU registry (89% of holding volumes) and 4.2 million CERs held in the

[18] This approach assumes that the distribution of host countries among unused CERs follows roughly the distribution of host countries among all issued CERs (Lo Re and Vaidyula 2019, p. 43).

Japanese registry (1.2% of volumes). An overview of holdings by Parties and registration dates is provided in Annex B.

In the following section, we discuss the holdings in registries in the order of magnitude of holdings.

Holdings in the EU registry (as of April 2018)

As of April 2018, 112 million CERs were held in entity holding accounts (i.e., by non-governmental actors) in the EU registry, representing 37% of total EUTL holdings, while 63% were held in Party accounts, totaling 189.5 million CERs. 37%, more than a third, of these holdings are CERs from activities registered prior to 2008, with 41.4 million of these CERs held by entities and 73.4 million held in Party accounts. Moreover, 58.3 and 112.8 million CERs are held in entity and Party accounts, respectively, for CERs from activities registered between 2008 and 2013. With 276 million, 92% of total CERs held in the EU registry are from activities registered before the start of CP2. Another 8% of holdings are a result of activities registered since 2013. In 2018, there were no CERs held in Party accounts from activities registered since 2016, but of course, by that time, not much issuance had been requested yet by activity developers.

Given the dominance of CERs from activities registered before 2013, it is not surprising that 277.4 million CERs, i.e., 92% of holdings, are from large-scale activities. Of these large-scale CERs held, 18%, i.e., 49 million CERs are from hydro projects. This is equivalent to 32% of all unused CERs from large scale hydro projects. 16% of large scale CER holdings stem from large-scale wind energy projects, which (with 46 million CERs) represents 28% of globally unused CERs of that type. 15% of large-scale CER holdings (41.8 million CERs) are attributable to HFC CERs, which corresponds to 39.2% of all unused HFC CERs on the market. 12% of EU holdings, i.e., 34 million CERs, are from N_2O activities, covering 26% of all unused CERs from that category.

10% of holdings, 28 million CERs, stem from landfill gas activities (both large and small scale), covering 34% of all unused CERs from that category. In addition, EU holdings relate to coal bed/coal mine activities (17 million, 6% of holdings), fossil fuel switch (15 million, 5.5%), EE own generation (14 million, 5% of holdings), fugitive (12,5 million, 4.5% of holdings) and biomass energy (8,9 million, 3% of holdings).

If one considers only CERs held from activities registered since 2013, the picture changes only slightly. Here, more holdings are recorded for entities (12.5 million CERs) than for Party accounts (13.2 million CERs). 93% of entity holdings stem from large scale activities, as do 87% of Party holdings. 39% of all holdings from activities registered since 2016 stem from large-scale hydro activities.

50% of holdings in the EU registry are CERs generated in China (151 million CERs, 97 million of these in Party holding accounts). In consequence, 35% of all unused CERs from China are held in the EU registry CERs and correspond to 12% of holdings from Indian activities, with 37 million are held in the EU registry, which corresponds also to 35% of all unused CERs of this type. Entities in the EU hold 6.5 million CERs from activities in Brazil. Party accounts hold a further 18 million CERs. In total, this corresponds to 8.1% of EU holdings and 28% of all unused CERs from activities in Brazil.

CERs from Asia correspond to 79% of holdings in the EU registry. Beyond Chinese and Indian CDM activities, 17% of EU holdings (50 million CERs) stem from activities in other parts of the Asian region. This corresponds to 24% of all CERs from these host countries that are left unused. A lesser share of holdings, 16%, is regarding activities in the Americas. If one excludes Brazil, another 24 million CERs from the Americas are held, which corresponds to 35% of all unused CERs from that region. Only 5% of holdings – totaling 14.6 million CERs – in the EU registry are related to activities in Africa. These holdings are almost evenly split among entity and Party holding accounts. These CERs amount to 30% of all unused CERs in respect to African CDM activities.

Holdings in the Swiss registry (as of April 2018)

In the Swiss registry, 90% of holdings – 15 million CERs – lie in entity holding accounts. It should be noted that many non-Swiss entities hold accounts in the Swiss registry as it was one of the first Kyoto Protocol registries. Party accounts hold a further 1.8 million CERs, 10% of the total. 13.8% of the total holdings are attributable to activities registered pre-2008, and a further 8.5% to activities registered post-2013. More than three quarters of CERs held in both types of accounts stem from activities registered in CP1.

The large majority of CERs, 81%, stem from large-scale projects. While HFC and N_2O abatement credits are negligible (0.1% of holdings in the Swiss registry), CERs from large-scale hydro and wind amount to 62% of total holdings. 3.3% of all unused CERs from large-scale hydro and wind are held in the Swiss registry. Further relevant categories are landfill-gas CERs, with 14% of all holdings, biomass energy as well as EE own-generation CERs which both constitute around 4% of the holdings.

The portfolio of holdings is clearly dominated by CERs from activities registered in Asian host countries, explaining 86.9% of the holdings. 68.9% of total holdings stem from Chinese activities. With 11.7 million CERs, 2.7% of all unused CERs from Chinese activities are held in the Swiss registry. A further 10% of holdings stem from Indian activities (1.6% of all unused Indian CERs) and a further 8% from other Asian host countries (0.6% of all unused CERs of that type).

A much lesser share of 2 million CERs – 11.5% of holdings – stems from activities in Latin America, and 4.5% of holdings are attributable to activities registered in Brazil. The Swiss registry holds 0.9% of all unused CERs from Brazilian CDM activities. Only 1.4% of holdings, 240k CERs, stem from activities registered in Africa.

Holdings in the Australian registry (as of 30 October 2020)

In the Australian registry, 16.4 million CERs are held, with 59% in entity accounts and 41% in Party accounts. 16.1% of all Australian holdings originate from activities registered prior to 2008 (2.6 million CERs). The great majority (10.7 million or 82%) of total holdings are from activities registered in CP1 of the KP, of which 44% lie in Party accounts. In the Australian registry, 11k CERs from activities registered in 2016 were held as of 2020.

Unsurprisingly, 93% of holdings are from large-scale projects. Australian entity and government accounts hold a comparatively low share of CERs from large scale industrial gas projects (HFCs and N_2O). These project types only represent 4% of holdings. 50% of holdings relate to large-scale hydro and wind projects. The rest stem from energy efficiency projects (own generation), fugitive and landfill gas projects with 12%, 8% and 8% respectively.

86% of holdings in the Australian registry stem from CDM activities in Asia. 51% of holdings (8.4 million CERs) are associated with Chinese CDM activities. Almost 2% of all unused CERs from Chinese activities are held in the Australian registry with an even split of entity and Party holdings. A further 18% of holdings relate to Indian CDM activities, with 3 million CERs, corresponding to 2.8% of all unused CERs from Indian activities. 2.7 million CERs and 16% of holdings are associated with other activities in the Asian region.

CERs from African CDM activities amount to 1.4 million CERs being held, which corresponds to 2.8% of all unused CERs from African activities. Only 5% of holdings (0.9 million CERs) correspond to CDM activities in the Americas, the majority (0.7 million CERs) coming from Brazilian CDM activities. The Australian registry thereby records holdings of 0.7% of total unused Brazilian CERs.

Holdings in the Japanese registry (as of 31 January 2021)

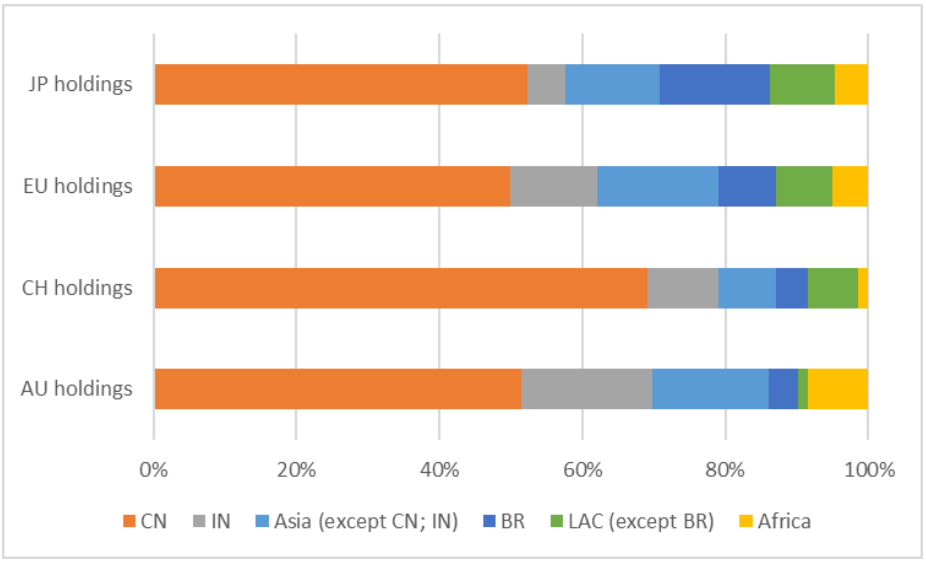
We are not able to disaggregate Party and entity accounts from the data shared with us by the Ministry of environment in Japan. Of the 4.2 million CERs held in the Japanese registry, more than half (57.6%) stem from activities registered pre-2008. The rest stems from activities registered between 2008 and 2013 (28%) and post-2013 (15%).

The holdings are mostly in respect to large-scale activities (84.3%). In total, 31% of holdings are in respect to CERs from HFC and N_2O abatement. Thereby, 0.6% of all unused CERs from these two project types are held in the Japanese registry. A further 21% of holdings is in respect to large scale hydro and wind, a lower share than in other registries.

Most holdings (52%) are a result of CERs issued for Chinese CDM activities. The Japanese registry records the holding of 0.5% of all unused CERs from China. A further 5.4% of holdings are CERs from Indian activities, and an additional 13% of holdings for CERs are from other Asian host countries. Surprisingly, the Japanese registry holdings are less dominated by Asian CERs than European registries. Instead, 24.5% of holdings are from CER activities in the Americas, with 15.4% of all holdings stemming from activities in Brazil. The Japanese registry holds 0.7% of all unused CERs from activities in Brazil. A further 4.6% of CERs come from activities in African host countries.

Figure 20 provides an overview of the host-country related characteristics of the different registries.

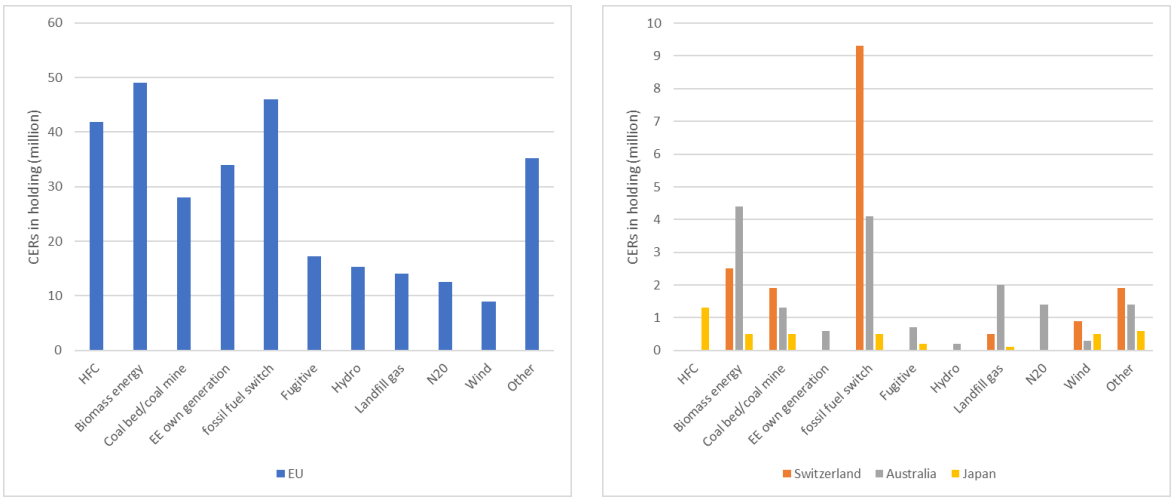
Figure 20: Host country shares (%) in the different buyer country registries



Source: authors, based on Betz et al. (2021). Note: BR - Brazil; CN -China; IN – India.

Figure 21 provides an overview of the project type in different registries, which differ significantly.

Figure 21: Project types in buyer country registries



Source: authors, based on Betz et al. (2021). Please note the differences in amounts (x-axis) between the registry data on EU holdings on the left-hand side and other registry holdings on the right-hand side.

What can we say about holdings in the CDM registry?

Due to the aggregated nature of reporting of unit holdings in the CDM registry, it is not possible to disclose project-level characteristics for CERs still held in the CDM registry.

However, understanding the characteristics of holdings in the national registries (to the extent we had access to the data) allows us to make some informed assumptions on the characteristics of holdings of CERs in the CDM registry. We do know that 48.7% of all unused CERs, amounting to 401 million CERs, are lying in the CDM registry, which includes the pending account – where according to information of the UNFCCC Secretariat, the vast majority of CERs are held – and holding accounts,

which includes 10 million CERs held by the trustee of the Adaptation Fund. 39.5% are CP1 units and 61.5% CP2 units.

Roughly 70% of all CERs from pre-2008-registered CDM activities must still be lying in the CDM registry, as well as 60% of CERs from pre-2013 activities and 67% of all pre-2016 activities. As we have limited reported holdings of CERs from post-2016 activities in national registries, a majority of these can be assumed to be held in the CDM registry.

64.5% of remaining large-scale CERs are estimated to still lie in the CDM registry, and it is assumed that over 80% of remaining unused HFC and N_2O abatement CERs lie there as well.

While over 70% of unused Brazilian CERs are estimated to still lie in the CDM registry, this is only the case for 60% of CERs from China and India. Two thirds of all unused CERs from African countries are also estimated to still lie in the CDM registry.

4. Lessons from the analysis of unused CERs for the PA era

In this chapter, we summarize key lessons for the Parties currently negotiating the rules for market-based cooperation under the Paris Agreement that relate to building a transparent and implementable system and reaching a compromise on the use of CERs in post-2020 carbon markets.

4.1. Limited transparency of CER holdings through regulatory 'slippage'

The Conference of Parties serving as the Meeting of the Parties to the KP (CMP) in 2005 adopted a decision with significant transparency requirements regarding the provision of disaggregated information on CERs (and other Kyoto units) traded. Meanwhile, Parties and the CDM Executive Board (CDM EB) adopted a far-reaching definition of confidentiality, restricting public reporting to aggregate information only. Few governments generally publish disaggregated information from their registries (most notably Australia). Some publish recent data (e.g., Switzerland, New Zealand) while others publish information only after a longer period (e.g., the EU initially only publicized data after five years which represents an entire NDC cycle in the PA context. Now, the EU publishes data after three years, as does Switzerland. We reproduce the decisions in a box below, given their importance:

Decision 3/CMP.1 and 13/CMP.1 require the CDM EB and Annex B Parties to:

- Have a **publicly accessible user interface** that allows any user to access all non-confidential information.
- Provide up-to date information on the accounts and the **identification of their representatives**; and
- Provide **detailed holding and transaction information, by serial number, for each calendar year** (including acquisitions, transfers, cancellations differentiated by purposes, retirements, carry-over, and holdings).

However, the operationalization of these requirements was circumvented completely by the confidentiality regulations in the different Annex B countries. In the end, the ITL administrator concluded that the aggregate information of Kyoto units published annually in the SEF and a reference to confidentiality regulations is sufficient to "satisfy the public information reporting requirement" […], "*[a]lso in recognition that information on individual account holdings and transactions has been declared confidential by the European Commission and several independent Parties*" (UNFCCC ITL Administrator 2015). This restriction of public information went unnoticed by most observers. The result is a very patchy landscape of public information available on national registries, with information made available by governments at different points in time and to different degrees of detail.

The UNFCCC Secretariat, under the guidance of the CDM EB, publishes all CER issuances by serial number and calendar year, but no disaggregated information on holdings and other transactions of CERs. The UNFCCC Secretariat and the CDM EB refer to common practice on confidentiality as established by Annex I Parties with respect to their Kyoto registries to explain their approach (CDM EB 2016). This practice was subject to some discussions by the CDM EB, but no decision could be taken on how to better balance transparency and confidentiality, e.g., by publishing the disaggregated information after some years.

There are some key lessons to be learned from disappointing experiences under the Kyoto Protocol that have led to the difficulties to establish a robust dataset discussed in the preceding sections and estimate the supply and demand balance on the international carbon market. In consequence, **the CMA should carefully consider making reporting requirements and information publicly available to enhance transparency on international trading of mitigation outcomes.** This is a prerequisite to safeguarding environmental integrity and requires defining (and clearly limiting) options to mark information as confidential. Parties and the A6.4M should be able to aggregate account-level information in public reports, anonymising account holder names but reporting on specific transactions and holdings of mitigation outcomes identifiable by a 'unique identifier', which could be a serial number that should be clearly and publicly linked to a specific cooperative approach or mechanism. The data should be publicly available after no more than three years, which is now common practice in EU and Switzerland. The UNFCCC Secretariat and experts undertaking review of Article 6 reports should be clearly mandated to assess Parties' compliance with these rules, and the Article 6.4 Supervisory Body should be required to report on this and forward systemic issues to the Article 15 Compliance Committee.

4.2. Where are the CERs? Implications for CER transition options

Negotiation interests of Parties are influenced to a certain extent by whether the countries (and the countries' private sector) are net holders of leftover CERs even after complying with CP2-commitments, or whether they are host countries of CDM projects, where the national private sector holds issued CERs or expects issuance of CERs to (re-)finance mitigation activities. However, as outlined above, the restricted accessibility of project-level information on holdings and final uses (retirement, cancellations, etc.) of CERs both within the CDM registry and in the national registries of most Annex B Parties renders a clear picture of negotiation interests difficult.

Beyond analysing the characteristics of unused CERs by registration date (see subsection 3.2), further and or additional parameters to restrict CER transition are elaborated in the following section.

4.2.1. Avoiding the carry-over of 'zombie' CERs

As discussed above, CERs from an expired CP must be mandatorily cancelled if held in national registries, in accordance with CMP decisions, and not carried over (see section 2.5). Very differently to what the CMP decision had envisaged, 36.3 million CP1 CERs continue to be held in national registries in the year 2021. However, they are basically 'zombie' units in the KP system, as they cannot be transferred out of their national registries. They can only be transacted within the registries, e.g., being 'voluntarily cancelled', noting that may include mandatory transactions under national law and offsetting on the voluntary carbon market.

It is unclear whether all CP2 CERs in national registries would have to be mandatorily cancelled if not carried over to a subsequent CP3. We note that some Parties advocate the definition of a CP3 but see it as extremely unlikely that a CP3 will find consensus, given widespread thinking that there is no further role for the KP in a PA world. As it is unlikely that any CERs will be used for compliance (though they may be used for voluntary offsetting purposes or under national law), this would affect the 247 million CP2 CERs held in national registries.

In any case, and to avoid non-enforcement of CMP decisions, Parties could decide to limit the transition of CERs into the PA to those held in the CDM registry (limiting the unused CP1 CERs to 154 million and CP2 CERs to 247 million). For these CERs, it can be assumed that no payment has yet occurred. If the main objective is to ensure investors can sell their CERs, this could be a 'landing zone' proposal. This would reduce the total amount of unused CERs to under 500 million CERs and reduce the amount eligible for transition by 56%. The majority of these CERs would stem from activities registered prior to 2016.

However, the legal challenges of compliance with cancellations obligations in the respective countries are not likely to be overcome, so use of these CP1 or CP2 CERs may not be preventable in other (non-PA) contexts.

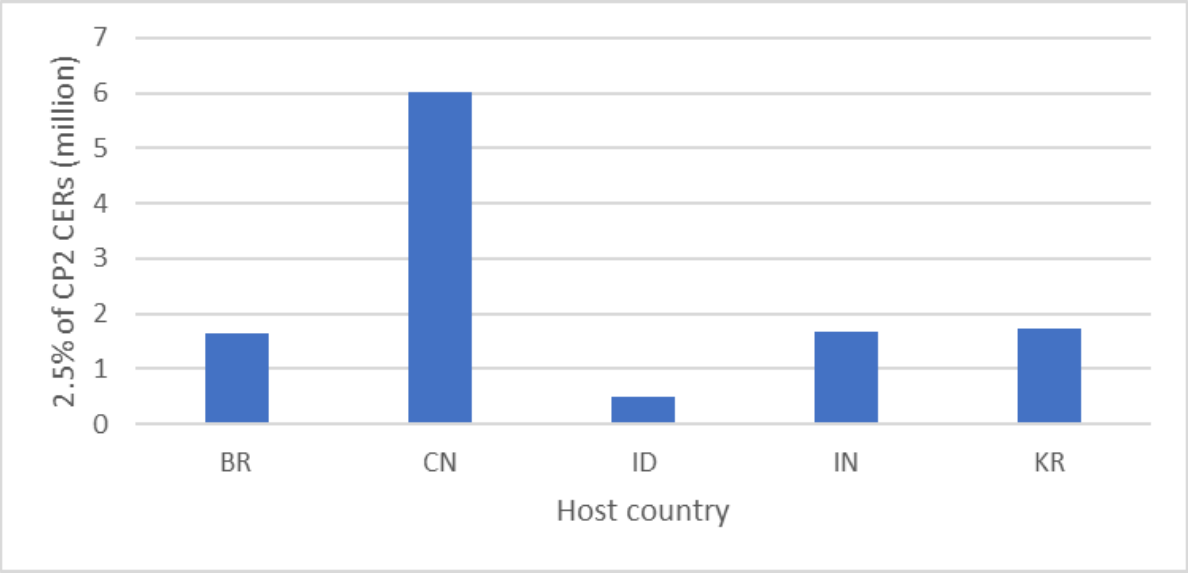
In the future, and especially in a more integrated carbon market, where certified mitigation outcomes may be used in different and overlapping systems, a mandatory cancellation of 'unused' ITMOs at the end of an NDC implementation period may be of little value. Instead, Parties should identify alternative means to ensure that only mitigation outcomes generated in a specific NDC implementation period (or carried over as per international rules) are eligible for use in that same period. This can be achieved through harmonised rules on 'unique identifiers' for ITMOs to be reported (publicly) by Parties and by the A6.4M.

4.2.2. Set quantitative limits for host countries' 'carry-over' of CERs

Apart from (or instead of) restricting CER transition to CERs held in the CDM registry, Parties are currently negotiating rules for host countries to transition CERs for their own use into the NDC

implementation period until 2030. Here, rules for carry-over should be harmonized with general rules for carry-over under Article 6 of the Paris Agreement. A precedent under the UNFCCC would be the carry-over restrictions adopted under the Doha Amendment to the Kyoto Protocol. A cap of 2.5% of issued CERs could be set for host countries in the PA era as well, to transition CERs from projects registered in CP2. Host countries would have the prerogative to identify the CERs eligible for carry-over up to this quantitative limit. Such a decision would be less restrictive as compared to a project registration date cut-off as of 31 December 2015, but significantly more restrictive than a project-level cut-off date as of 31 December 2012. The implications for the top five countries with most CDM projects are depicted in Figure 22, showing that 6 of the 16 million CERs would come from Chinese CDM activities.

Figure 22: Analysis of a 2.5% carry-over limit for CP2 CERs for the selected host countries



Source: authors, based on Betz et al. (2021). Note: BR – Brasil; CN – China; ID – Indonesia; IN – India; KR – Korea

Parties could additionally decide whether these CERs carried over would be eligible for domestic use only or also for international trading.

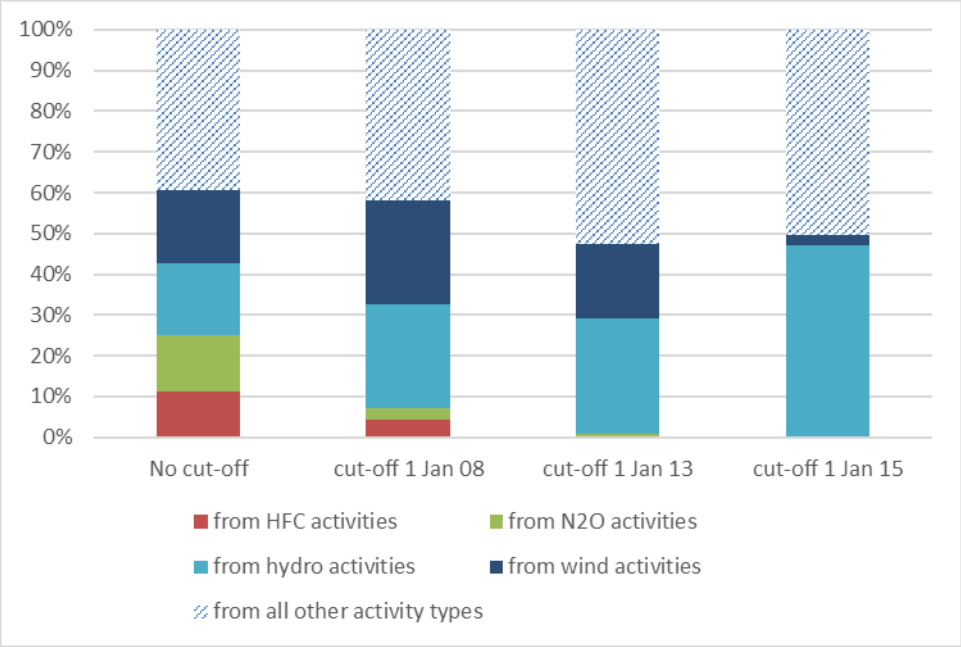
4.2.3. Exclude CERs from certain project types

In addition to restrictions by date of project registration, project types should be excluded which are taken up as a mandatory action – and financed - in other multilateral environmental agreements (e.g., destruction of HFC-23 is mandatory under the Kigali Amendment of the Montreal Protocol) and have high risks of negative environmental impacts, e.g. through perverse incentives to increase production. Many observers have argued to expand this exclusion to projects that have a low risk of discontinuation due to continued generation of revenues. We would like to note that from a point of view of investment certainty, the case for exclusion of the latter type of projects is weak, especially if they fulfilled the additionality criteria at the point of registration. Marcu et al. (2020) consider in their consideration of options the following project types to be potentially excluded: HFC-23, N_2O, hydro power projects above 20 MW as well as forestry (already excluded from our assessment of unused CERs).

In the dataset on unused CERs (Betz et al. 2021), excluding HFC, N_2O, hydro and wind projects from transition would reduce the amount of *unused* CERs to be transitioned as follows:

- From 955 to 715 million CERs if excluding HFC and N_2O, with further limitation to 377 million CERs if also excluding hydro and wind activities with no registration-based cut-off date, reducing supply by 25% or up to 60%.
- From 596 to 553 million CERs if excluding HFC and N_2O, with further limitation to 249 million CERs with a registration-based cut-off date of 31 December 2007, reducing supply by 7% or up to 58%.
- From 115 to 61 million CERs with a registration-based cut-off date of 31 December 2012 if excluding hydro and wind, reducing supply by 47%. Combined with a 2013 registration limitation, a further exclusion of HFC activities has no additional effect. The 2013 cut-off would limit eligible CERs from N_2O activities to 0.9 million CERs.
- From 8.6 to 4.3 million CERs with a registration-based cut-off date of 31 December 2015 when excluding hydro and wind, reducing supply by 50%. This late registration cut-off excludes any CERs from HFC and N_2O abatement.

Figure 23: Share of selected activity types in unused CERs



Source: authors, based on Betz et al. (2021).

The effect of exclusions of all four activity types is generally higher for early cut-off dates. A late-registration-based cut-off effectively excludes CERs from HFC and N_2O abatement.

4.2.4. Summary of options for negotiations

Parties have two fundamental options in negotiations: allowing for (some) CERs to be used in NDCs and excluding (some) CERs from such an eligibility. Both options have consequences.

If Parties agree on setting criteria to render CERs eligible for use against post-2020 NDC targets, they can choose different parameters to restrict that eligibility. Making CERs eligible in the post-2020 carbon market essentially leads to banking of mitigation outcomes between compliance periods of different regimes, the KP and the PA, under the UNFCCC. In contrast to national ETS, banking has in the past been restricted under the KP, with an upper limit of 2.5%. Ideally, Parties would agree on general rules of banking in the PA that then guide a decision on CERs. The easiest way to do this would be to continue the precedent made by the KP, i.e., allow banking of 2.5% of CERs generated in CP2, i.e., 2013-2020.

Instead of generic banking rules, Parties can agree on specific rules for the use of CERs. There are several options for restricting the use of CERs that can be combined. We list the options here by their impact on the unused CER portfolio.

A) Options that result in more 400 million unused CERs eligible in post-2020 carbon markets are:
1. Not restricting the eligibility of CERs, which leads to a 'transition' of all unused CERs.
2. Excluding project types that are mandated by other regimes and have universally acknowledged negative impacts on environmental integrity. For instance, Parties could exclude CERs from HFC and N_2O activities. However, agreement on a negative list may prove very difficult in negotiations. Setting a 2013 or 2016 activity registration cut-off date has a similar effect on the type of eligible CERs as excluding the large-scale industrial gas projects. In our analysis, excluding HFC and N_2O would reduce supply compared to option 1 by 25%. Excluding also hydro and wind has a stronger impact, especially if combined with later registration date cut-offs.
3. Restricting eligible CERs to those registered after 2008, which marks the start of CP1 of the KP and excludes CERs from the early activities under the CDM. In our analysis, this would reduce supply compared to option 1 by 38%.
4. Restricting the eligible CERs to those remaining in the CDM registry. This would enable activity participants to sell CERs from their projects and the trustee of the Adaptation Fund to monetize share of proceeds, while blocking transition of CERs stemming from secondary transactions. This would be in accordance with CMP rules where CERs from the CDM registry were never subject to mandatory cancellation. In our analysis, this would reduce supply compared to option 1 by 58%.

B) Options that result in less than 25 million unused CERs eligible in post-2020 carbon markets are:
5. Restricting the eligible CERs to those from activities registered in CP2 of the KP, which were to a large degree affected by the crash in carbon market prices. In our analysis, this would reduce supply compared to option 1 by 97%.
6. Give host countries a say in the way they want to achieve their NDCs and capitalize on CDM experience: set quantitative limits for carry-over but leave identification of CERs up to host countries (Option 6). Such a limit could be set in accordance with KP rules at a level of 2.5% of

CERs generated in a country in the previous compliance period. This would allow host Parties to decide which types of projects they want to promote in their domestic climate policy context. Carry-over would have to be reported with underlying serial numbers, as done under the KP. If countries would agree on allowing host countries to carry-over CERs for up to 2.5% from activities registered in CP2, this would result in an allowed carry-over of 16 million CERs. Compared to option 1, this would limit supply by 98%.

7. Restricting the transition to those from activities registered after 2015, to allow for programme developers with more recent investment decisions in the CER to ensure a return on their investment. Carry-over of CERs into the PA NDC implementation periods can be limited with the objective of avoiding that lowered emission levels generated by past CDM projects and considered in the calculation of NDCs before their start are then 'double counted' in NDC implementation from 2020. This would speak in favor of a cut-off date in 2016, which severely restricts the amount of CERs eligible to 0.9% of the overall unused CERs and excludes CERs from large-scale industrial gas activities, while benefitting a broader range of host countries when compared to other limitation scenarios.
8. Finally, Parties could decide not to render any CERs eligible for use in post-2020 NDCs and related compliance markets.

All the different limitation options can be combined to achieve a balance of different objectives pursued by Parties that object to and support a decision on allowing for transition to CERs. In addition, Parties must also consider impacts of restrictions on likelihood of potential future supply of pre-2020 CERs that could emerge if credit prices under Article 6 are sufficiently attractive.

If Parties to the PA decide not to allow for the use of CERs in NDCs, or only make some CERs eligible, they must decide on the fate of the ineligible CERs. If only CERs in the CDM registry are eligible for use towards NDCs, CERs in national registries are not. As per the rules of the KP, CERs not carried over must be mandatorily cancelled (a rule that never applied to the CDM registry). Annex B Parties to the KP could set a deadline for the mandatory cancellation and allow private owners of CERs to voluntarily cancel CERs beforehand, which would allow selling them for non-compliance uses (i.e., on the voluntary carbon market).

In the context of all other restrictions of CERs, the CMP could decide to mandatorily cancel all remaining CERs after a certain period, in which CERs could continue to be cancelled for voluntary purposes. A mandatory cancellation results in a de-facto expropriation of the programme developers or owners of the CERs and has proven legally challenging in several Annex B Parties and is assumed to be the main reason why so little mandatory cancellations have taken place to date. Parties could multilaterally (or unilaterally) decide on compensation schemes. Compensation schemes should avoid windfall profits and differentiate compensation amounts by type of project. For example, compensation for expropriated industrial gas CERs could be offered at rates of around USD 1/CER, whereas for small-scale household energy efficiency activities, it could be set at around USD 5. For larger, non-industrial gas projects, a value of USD 4/CER would seem appropriate, which was the level offered by the World Bank-operated carbon funds for several years before 2005. Regarding project types with many different developers, reverse auctions could be held to discover the appropriate amount for compensation.

Instead of mandatory cancellations, CERs could continue to be held in a UNFCCC registry, where they can be voluntarily cancelled. This would allow countries to continue to use the function of CDM voluntary cancellation in the context of domestic carbon market schemes or offsetting of carbon taxes (that would not be accountable towards NDC achievement). It would also allow for the continued use of CERs on the so-called voluntary markets or non-UNFCCC compliance regimes, e.g., the Carbon Offsetting and Reduction Scheme in International Aviation (CORSIA).

Instead (or in addition to) a voluntary cancellation, CERs could be used as a 'reserve' that (host) Parties can access to compensate for underachievement against their NDC targets under specific circumstances. While such a reserve has been proposed in Article 6 negotiations, it remains unclear how that could be operationalized and how it would serve the purpose of giving CER investors an opportunity to generate a return on their investment prior to the end of the accounting period of the first NDC implementation period, which is estimated to be 2032 or 2033 in most cases. Historically, hopes for a compensation of expropriation through an open-ended process have generally not worked, see e.g., the hope of investors in Russian bonds issued by the pre-communist regime.

4.3. Is the foreseen infrastructure for PA carbon markets up to its tasks?

Beyond the relevance of transparency on CER transactions for the question of their eligibility in a PA compliance context, there are lessons to learn from the current system under the KP for the recording, reporting and accounting of mitigation outcomes in the context of the PA. Given that the PA has no strong compliance mechanism, transparency is key to enforce its implementation through both 'naming, shaming and praising' of Parties by other governments or the international community including NGOs. The centrepiece of the PA is therefore the 'Enhanced Transparency Framework' (ETF) introduced by Article 13 of the PA that builds on the reporting and review processes under the UNFCCC and KP, with the aim of overcoming the bifurcation of obligations between industrialized and developing countries, while acknowledging different capacities and national circumstances. The modalities, procedures and guidelines (MPGs) of the ETF were adopted at COP24 in Katowice in 2018.

To deliver on these requirements on transparency and safeguard environmental integrity in international carbon markets, new infrastructure as well as new processes of reporting and reviewing will be set up under the ETF, in the Article 6.2 guidance and in the rules, modalities and procedures of the A6.4M of the PA (Michaelowa et al. 2020b).

Under the ETF, Parties must submit Biennial Transparency Reports (BTRs) that contain information on the status of their NDC implementation and achievement. This will include information on authorization, transfer and use of ITMOs. Prospectively, ITMOs transfers are suggested to be recorded in both national registries and a centralized infrastructure under the UNFCCC, the Centralized Accounting and Recording Platform (CARP) which will include an 'Article 6 database'. There is still a long way to go to operationalize the reporting and review processes and establish the necessary infrastructure for market-based cooperation under the PA, but lessons learned from the Kyoto Protocol's flexible mechanisms should be considered in this process.

Based on the shortcomings identified in the previous chapter, we provide some recommendations for the design of the Article 6 database in the CARP as well as the design of the Article 6.4 registry for the consideration of Parties. In our recommendations, we assume that the Article 6 database, CARP and A6.4M will be adopted as currently foreseen in negotiations (for detailed information, see Michaelowa et al. 2020b).

Under the PA, although it is a bottom-up regime, accounting must be centralized and harmonized to ensure environmental integrity and the avoidance of double counting. For us, this means that all ITMOs (which includes Article 6.4 ERs) that are authorized for transfer, (first) transferred, acquired, held or used by participating Parties must be tracked in the Article 6 database. Information must include the host region and country of project, type of activity, and vintage of the mitigation outcomes through a unique identifier. At least for the A6.4M, this must be a serial number that is immutable.

These unique and immutable serial numbers must be accessible to observers to access all necessary information of unit holdings and transfers at all stages of the ITMO/Article 6.4 cycle. Ideally, there should be international guidance on these identifiers for ITMOs in general, which allows higher comparability of units traded internationally. In the A6.4M, a project-ID should allow observers to search for and access all project-related documentation.

A key lesson from the KP is that carbon credits issued by a UNFCCC crediting mechanism may be used for a broad range of purposes. Therefore, operative and reporting requirements for national registries should consider these different uses and allow for transparent and granular reporting on different use cases.

Any tradable mitigation outcome (allowances, credits) is an object of speculation. Thus, Parties and private sector actors may have an interest in concealing their strategic holdings and transfers. However, weighing economic interests against the gains through enhanced transparency should favor the (anonymized) disclosure of project-level information of holdings, transfers, and carry-overs. Here, new solutions which avoid the 'race to the bottom' to apply confidentiality to any sort of disaggregated information must be found to enhance transparency. Especially, as there will be no corresponding ITL to verify transactions, public scrutiny on the validity of carbon market transactions will become key.

Over the medium term, use of distributed-ledger (blockchain) technology could enhance the overall efficiency, security, and reliability of the recording, reporting and reviewing system, subject to further assessment of benefits and constraints of its implementation.[19] This may be needed in particular if in the context of the PA, where in the absence of an ITL, Parties must ensure the validation and verification of their data transfers between registries through other means.

[19] For ongoing piloting initiatives in this regard, see e.g. the Climate Ledger Initiative (CLI) or a World Bank WBx talk. There is also a blockchain working group under the Registry System Administrators Forum that includes registry administrators but also developing country experts. It noted the impossibility of undoing or cancelling fraudulent or otherwise erroneous transactions owing to the immutability of the ledger and the diverse regulatory landscape, including illegality of some types of blockchains in several countries. Therefore, the benefits of blockchain technology must be carefully assessed further.

5. Conclusions

Various proposals for limiting CER transition from the Kyoto to the Paris Agreement market mechanisms have been made, for example the introduction of cut-off thresholds for the registration date of projects generating eligible CERs, as well as project type specific CER eligibility criteria. To enable negotiators to make well-informed and evidence-based decisions about CER transition into the post-2020 period, this study has assessed quantitative implications of several such options regarding the volume of CERs transitioned, based on data regarding CERs which are currently unused and therefore potentially available for such a transition. The study uses a combination of publicly accessible data, as well as supplementary data made available by several governments, and thus builds on a unique and up-to-date data base. Unused CERs conservatively amount to about 0.8-0.9 billion, about 40% of total issuance to date. The volume of CERs in the CDM registry alone reaches 0.4 billion. Regarding registration vintages, the bulk of unused CERs stems from activities registered before 2013. Therefore, all post 2013 options limit CER transition to well below 30 million. The host countries most vocal for unlimited CER transition are also those that have the highest volume of unused CERs to date. Africa would benefit quite strongly from a 2016 cut-off, given that is has achieved significant issuances from recently registered projects. Moreover, the study situates its findings in the broader context of the historical evolution of international carbon markets, their governance architecture and reporting and review processes, particularly regarding learning from past experiences under the CDM and improving the efficacy of the Paris Agreement market mechanisms under Articles 6.2 and 6.4. All in all, the study shows that all transition options and interests need to be carefully considered in the run-up to finalizing the design of Paris Agreement market mechanisms.

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Annex A: Analysis of used CERs in comparison to unused CERs

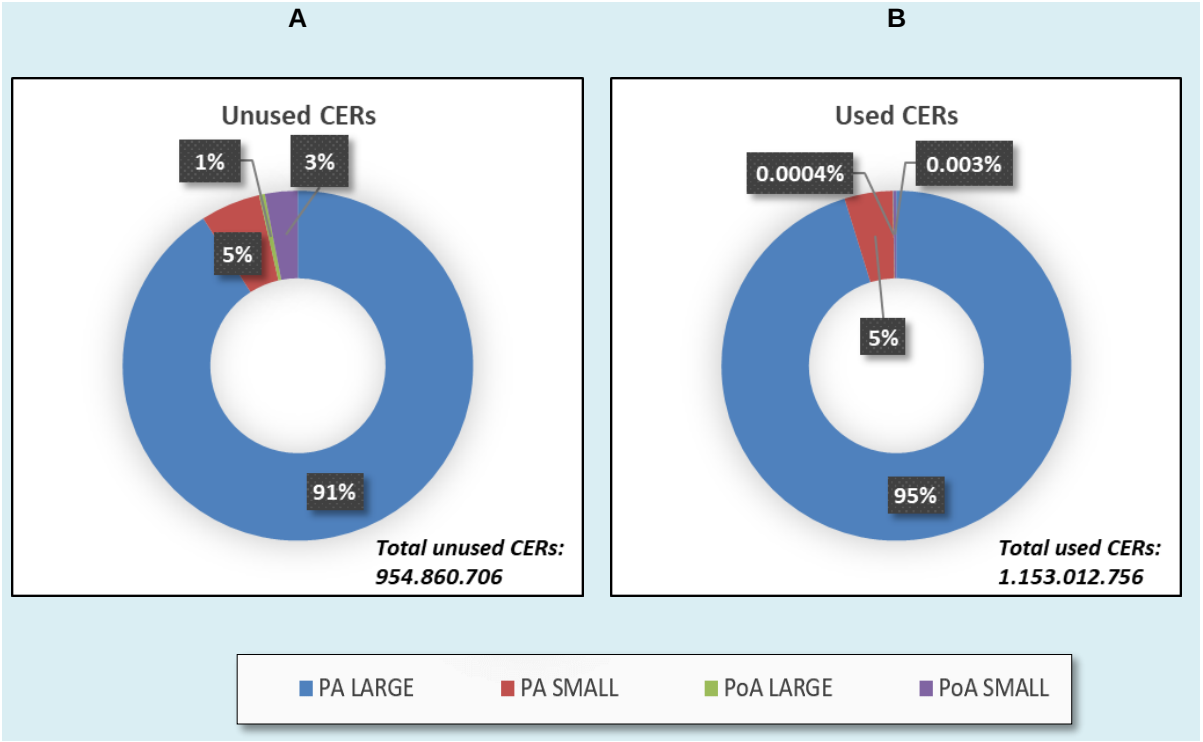
In comparison of the characteristics of used versus unused CERs, the following are the key insights:

- Almost all CERs (95%) that were 'used' (retired and cancelled) stem from large-scale activities (1.4bn CERs). With 0.87 bn CERs, large-scale activities also delivered on the vast majority (90%) of unused CERs.
- 96% of retired CERs stem from large-scale project activities, while only 4% are from small scale activities, and the retirements from PoAs are negligeable (partially because PoAs were introduced late as a concept). The picture only looks slightly different when considering voluntary cancellations. Here, cancellations from small-scale PoAs amount to 2% (0.03bn CERs) of voluntary cancellations. CERs from large-scale PAs make up 89% of voluntary cancellations with 0.16 bn CERs.
- China is the host country of both the majority of used (0.6bn) and unused CERs (0.4bn), followed by India with 0.15bn used CERs and 0.1bn unused CERs. While South Africa and Argentina are among the top ten host countries of used CERs, they are no longer on the list of unused CERs. The opposite holds true for Qatar, Uzbekistan and Vietnam.
- Interestingly, HFCs were the main project type of all used CERs by far (38%), with over 40% of retirements stemming from HFC projects (0.41bn CERs), while only representing 11% of all voluntary cancellations (a further 0.02bn CERs). N_2O projects represent 21% of all retirements (0.2 bn CERs), but only 14% of all voluntary cancellations (0.03bn CERs)[20]. Hydro projects represent 14% of all retirements (0.13bn CERs) and 15% of voluntary cancellations (0.03bn CERs), with the majority (79% and 83% respectively) coming from large-scale hydro projects. Wind projects only constituted 7% of all retirements (0.067bn CERs), but over a fifth of all voluntary cancellations (0.04bn CERs). While landfill gas activities only make up 2.6% of all retirements, they delivered the CERs of 12.5% of all voluntary cancellations.
- Almost half of all voluntary cancellations occurred in the EU (46%), followed by the CDM registry, where a further 37% of all voluntary cancellations occurred. Australia administered 8.2% of all voluntary cancellations, followed by Switzerland with 6% and New Zealand with 3%. Only 0.2% of all voluntary cancellations occurred in the Japanese registry.
- A close look offers insight into varying preferences of buyers for voluntary cancellation purposes. In the EU, where most of voluntary cancellations that we aggregated occur (46.2%), a quarter of these voluntary cancellations were made for HFC projects (24.3%), 22.9% for wind projects, followed by hydro projects (17.3%). Around 4-6% of voluntary cancellations were made for EE own-generation, landfill gas and fossil fuel switch activities. In the CDM registry, where 37% of all voluntary cancellations took place, the most popular project types are N_2O (27.2%), hydro (18.5%) and wind (17.4%), making up over 60% of cancellations.
- In the Australian registry, almost half of all voluntary cancellations (48.7%) can be attributed to wind projects and a further 21.7% to landfill gas activities. In the Japanese registry, a third of

[20] Under the Nitric Acid Climate Action Group (NACAG), further voluntary cancellations of up to 0.02bn tCO_2e from both CDM and voluntary carbon market standards may occur for post-2018 vintages.

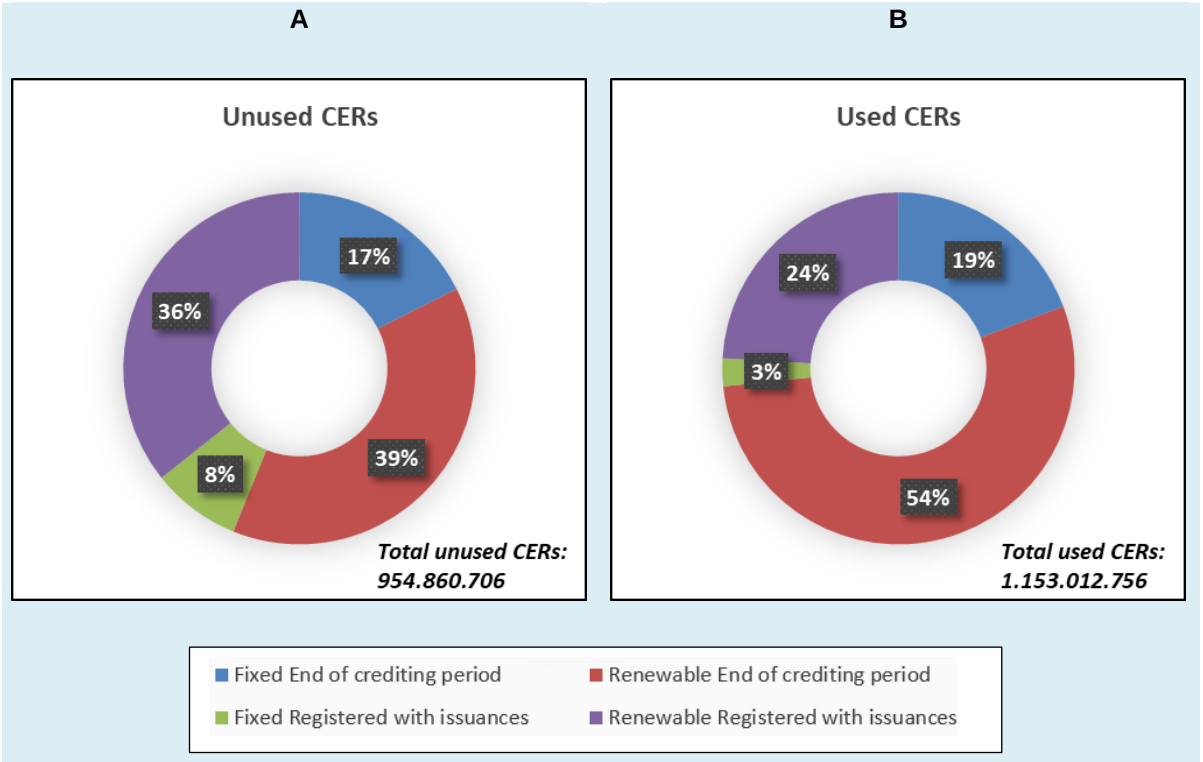
voluntary cancellations was made for landfill gas activities, and around 24% each for coal bed activities and wind activities. Together, these three project types make up over 80% of all Japanese administered voluntary cancellations. In the New Zealand registry, voluntary cancellations were very diverse, with many small cancellations for different project types. The only dominant category is N_2O abatement, with 35% of all voluntary cancellations. In Switzerland, over a third of voluntary cancellations was for landfill gas activities (34%), followed by N_2O abatement with 28% and hydro projects with 11%.

Figure 24: Comparison of unused and used CERs by scale of activities (no cut-off date)



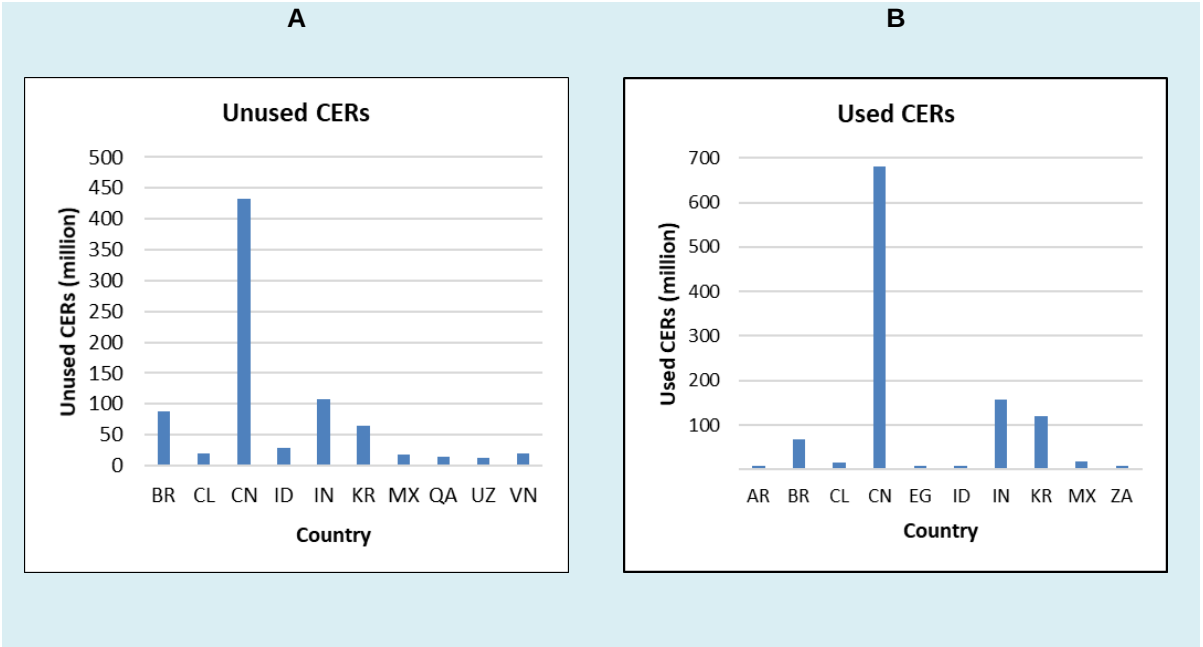
Source: authors, authors, based on Betz et al. (2021). Note: PA- Project activity; PoA - Programme of activities.

Figure 25: Comparison of unused and used CERs, by status of project activity (no cut-off date)



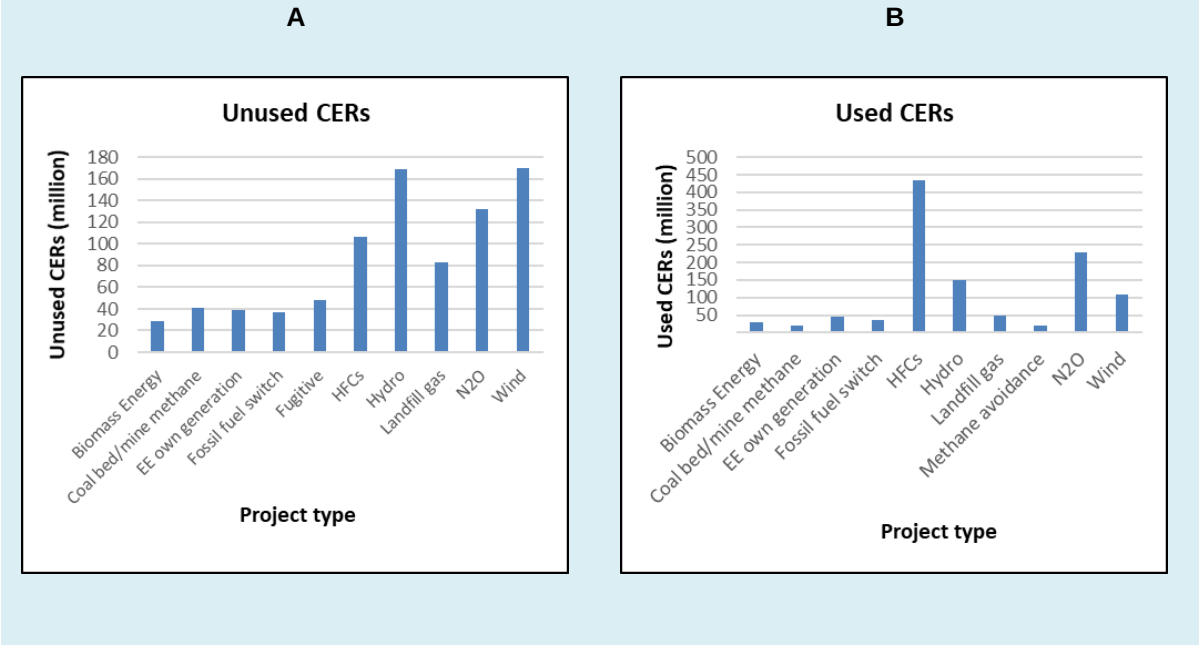
Source: authors, based on IGES (2020a-c), UNFCCC (2021a, b and d) and supplementary national registry data.

Figure 26: Comparison of unused and used CERs by key host countries (no cut-off date)



Source: authors, based on Betz et al. (2021). Note: AR – Argentina; BR - Brazil; CL -Chile; CN - China; EG – Egypt; ID - Indonesia; IN - India; KR - Republic of Korea; MX - Mexico; QA - Qatar; UZ - Uzbekistan; VN - Viet Nam; ZA – South Africa.

Figure 27: Comparison of unused and used CERs by main project types (no cut-off)



Source: authors, based on Betz et al. (2021). Note: EE - Energy efficiency; HFCs – Hydrofluorocarbons; N2O - Nitrous oxide. See UNEP DTU (2020) for exact descriptions of project types.

Annex B: Annex B country registry holdings

Table 8: Annex B country registry holdings by activity registration year

Registration years	Sum Unused CER	Sum AU Entity Holdings	Sum AU Party Holdings	Sum AU Total Holdings	Sum CH Entity Holdings	Sum CH Party Holdings	Sum CH Total Holdings	Sum EUTL Entity Holdings	Sum EUTL Party Holdings	Sum EU Total Holdings	Sum JP Total Holdings
2004	419,197	0	0	0	0	0	0	18,161	165,789	183,950	140,222
2005	105,844,877	59,702	0	59,702	1,564	490	2,054	4,938,262	19,032,238	23,970,500	208,601
2006	126,182,183	681,613	94,333	775,946	1,276,033	233,074	1,509,107	19,619,038	22,555,829	42,174,867	1,615,203
2007	126,911,879	1,204,364	597,128	1,801,492	714,906	113,381	828,287	16,862,108	31,650,064	48,512,172	468,475
2008	59,305,348	455,623	117,411	573,034	1,783,444	488,817	2,272,261	7,825,135	15,060,122	22,885,257	343,276
2009	126,564,072	574,019	851,074	1,425,093	1,715,131	484,932	2,200,063	14,631,615	25,931,216	40,562,831	382,389
2010	75,711,758	1,295,131	602,695	1,897,826	809,173	41,356	850,529	8,914,678	19,951,288	28,865,966	150,050
2011	124,705,305	1,718,543	1,924,727	3,643,270	3,434,823	379,445	3,814,268	15,789,898	26,359,445	42,149,343	82,706
2012	93,745,601	1,946,542	1,247,115	3,193,657	4,009,511	19,671	4,029,182	11,175,792	15,544,392	26,720,184	217,910
2013	90,483,397	1,548,086	1,332,723	2,880,809	1,350,953	2,262	1,353,215	12,358,171	12,576,760	24,934,931	615,196
2014	6,316,228	97,390	0	97,390	98,436	26	98,462	101,654	584,205	685,859	0
2015	10,079,581	1,100	0	1,100	0	0	0	0	55,031	55,031	0
2016	4,185,130	1,362	0	1,362	0	0	0	0	0	0	0
2017	688,270	0	0	0	0	0	0	0	0	0	0
2018	1,809,030	0	0	0	0	0	0	0	0	0	0
2019	820,986	10,027	0	10,027	0	0	0	0	0	0	0
2020	1,087,864	0	0	0	0	0	0	0	0	0	0
Total	**954,860,706**	**9,593,502**	**6,767,206**	**16,360,708**	**15,193,974**	**1,763,454**	**16,957,428**	**112,234,512**	**189,466,379**	**301,700,891**	**4,224,028**

Source: authors, based on Betz et al. (2021). Note: AU – Australia; CH – Switzerland; EUTL – European Union Transaction Log; JP – Japan.

Annex C: Listing of publicly available data sources

Table 9: Overview of international public data sources

Public data sources identified	Description
IGES (2020a) - Kyoto Units All Transaction Data	Lists total issuance of CERs by country and CP and calculates remaining stock of CER by subtracting retirement by Annex 1 countries, admin cancellations and voluntary cancellation from total CER issuance (CP1). For remaining CERs in CP2, only voluntary cancellation is subtracted from total CP2 CER issuance. Data comes from true-up reports.
IGES (2020b): Kyoto Units Transfer Database CP1 and CP2	IGES's Kyoto Units Transfer Database (CP1) aims to provide compiled information on issuance, international transfer, retirement, and cancellation of Kyoto units from each Annex I country or among different Annex I countries for the first and second commitment period of the Kyoto Protocol (in separate Excel files). The information is extracted from publicly available sources on national registries from the UNFCCC website.
IGES (2020c): CDM Project Database	IGES CDM Project Database aims at providing information to be utilized for research and analysis on the process of CDM project development, credit issuance, and the status of its procedures. The information of relevant items is extracted from the publicly available sources on the UNFCCC website. IGES and UNFCCC signed an MoU for data exchange.
UNEP DTU CDM Pipeline	Project-level data can be filtered out using hand-made filter functions (drop-down menu not available) for any country, including for voluntary cancellation.
CDM Registry (2020)	Information on CER validation, registration, issuance, first issuance, methodologies, DNA, process time and LDCs – what is extractable for China is, for instance, raw data on trends of issuance of CERs over time (unit: million CERs/month)
Voluntary cancellation registry CDM Data offset platform	Information on CER volumes, project reference number, CP, reasons for offsetting, with names of persons/entities.
UNFCCC final compilation and accounting reports for CP1 (2016)	Information on Annex B Party CP1 CER holdings, retirements and cancellations at the end of the true-up period of the first commitment period.
UNFCCC annual compilation and accounting reports for the second commitment period (2016-2019)	Information on annual Annex B Party holdings, retirements and cancellations of CP2 CERs. Information on Annex I countries without commitments in CP2.
National Inventory Submissions by Annex-I-Parties- supplementary information on KP units in Standardized Electronic Format (SEF), 2003-2020	Information on aggregate stocks and annual flows of CERs, differentiated by CP1 units and CP2 units, available in Annex-I-national registries. Includes information on Party and entity holdings, internal and external transactions, provenance of CERs (CDM Registry or national registries) and transaction to other national registries, information on cancellation, voluntary cancellation and retirement. Final values are available until 2019.

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