

Supplementary information for

Demand for low-quality offsets by major companies
undermines climate integrity of the voluntary carbon market

Table S1. Relative share of offsets retired by the twenty studied companies compared to all retirements made globally on each registry over 2020-2023

Registry	Global total (Mt CO ₂ e)	Twenty company total (Mt CO ₂ e)	Global share (%)
Clean Development Mechanism (CDM)	120.03	26.41	22.00
Gold Standard (GS)	97.56	5.16	5.29
Verified Carbon Standard (VCS)	428.72	102.57	23.93
Total	646.32	134.14	20.75

Data from registry websites: CDM¹, GS² and VCS³. The global volume of CDM credits reflects units voluntarily cancelled through the regular CDM registry process and excludes those processed via the online platform.

Table S2. Overview of twenty studied company's net-zero plans and use of offsets

Company	Sector	Country of headquarters	Claim or pursue net-zero?	Target year	Scope 1 & 2	Scope 3	Use offsets to compensate own emissions?	Details	Source 1	Source 2
Shell	Energy	Netherlands	Y	2050	Y	Y	Y	Also supplies carbon-neutral products/services such as LNG cargos and fuel purchasing for fleets and individual drivers.	Link	Link
Delta Airlines (Delta)	Airline	USA	Y	2050	Y	Y	Y	Also supplies carbon-neutral flights to passengers.	Link	Link
Volkswagen	Automotive manufacturing	Germany	Y	2050	Y	Y	Y	Also offers customers the opportunity to choose carbon-neutral production and delivery when purchasing electric vehicles.	Link	Link
Banco Votorantim BV (Banco BV)	Finance	Brazil	Y	2030	Y	-	Y	Asides from operational emissions, also offsets emissions caused by vehicle loans.	Link	Link
Eni	Energy	Italy	Y	2050	Y	Y	Y	Also supplies carbon-neutral products/services such as LNG cargos.	Link	Link
Telstra	Telecommunications	Australia	Y	2050	Y	Y	Y	Claims to have reached carbon-neutral operations in 2020. Also offers customers carbon-neutral mobile phone and Internet plans.	Link	-
Audi	Automotive manufacturing	Germany	Y	2050	Y	-	Y	Claims to have reached carbon-neutral operations for plants in Győr and Brussels. Is aiming for carbon-neutral operations for all plants by 2025.	Link	Link
Takeda	Pharmaceutics	Japan	Y	2040	Y	Y	Y	Target for 2035 concerns scopes 1 and 2. Target for 2040 concerns scope 3.	Link	Link
Sasol	Energy, Chemicals	South Africa	Y	2050	Y	Partial	Y	-	Link	-
DPD	Logistics	France	Y	2040	Y	Y	Y	Claims to deliver carbon-neutral parcels at no extra cost to customers. Has limited offsetting of scope 1-3 emissions to 10% for 2040 goal.	Link	Link
Boeing	Airplane manufacturing	USA	Y	2020	Y	Partial	Y	Claims to have reached carbon neutral across manufacturing and operations (Scope 1-2) since 2020.	Link	Link
Chevron	Energy	USA	Y	2050	Y	Partial	Y	Also supplies carbon-neutral products/services such as LNG cargos and fuel purchasing for fleets and individual drivers.	Link	Link

Gucci	Fashion manufacturing	Italy	Y	2050	Y	Y	Y	Claimed to have been carbon neutral across direct operations and supply chain (Scope 1-3) since 2018. It dropped these claims in 2023.	Link	-
PetroChina	Energy	China	Y	2050	-	-	Y	Also supplies carbon credits to other clients.	Link	
easyJet	Airline	England	Y	2050	Y	-	Y	From 2019 to June 2023, offset the carbon emissions from the fuel used for all flights free of charge. Also supplies carbon-neutral flights and hotels/transfers at holiday destinations to passengers.	Link	Link
EY Global (EY)	Consulting	England	Y	2025	Y	Y	Y	Claims to be carbon negative since 2021 and to avoid or remove more carbon than emitted from own operations.	Link	Link
Norwegian Cruise Line Holdings (Norwegian CL)	Marine transportation	Norway	Y	2050	Y	Partial	Y	-	Link	Link
Yamato	Logistics	Japan	Y	2050	Y	-	Y	Claims to have achieved carbon neutral parcel delivery since 2022.	Link	Link
Hu-Chems Fine Chemicals (Hu-Chems)	Chemicals	South Korea	-	-	-	-	-	-	-	-
Skoda	Automotive manufacturing	Czech Republic	Y	2050	Y	Y	Y	Also offers customers the opportunity to choose carbon-neutral production and delivery when purchasing electric vehicles.	Link	Link

Data from company websites and Net Zero Tracker⁴. Cells marked with ‘-’ indicate cases where insufficient evidence was available. Company names in brackets indicate abbreviations used throughout the paper.

Hu-Chems	1.82	0.63	–	–	2.45	–	–	–	–	–	–	–	–	–	–
Skoda	–	0.58	0.64	1.21	2.42	–	–	–	–	–	–	–	–	–	–
All companies	20.12	38.66	39.52	32.46	130.76	0.28	1.11	1.13	0.56	3.09	–	0.04	0.02	0.23	0.29

Years with no retirements in that category are marked with ‘–’. Total columns show the sum of all retirements made over 2020-23 for that category of offsets. Some volumes shown in total columns may not match volumes in individual years due to rounding of decimal places.

Hu-Chems	100.00	100.00	-	-	100.00	-	-	-	-	-	-	-	-	-	-
Skoda	-	100.00	100.00	100.00	100.00	-	-	-	-	-	-	-	-	-	-
All companies	98.64	97.10	97.17	97.60	97.48	1.36	2.80	2.78	1.69	2.30	-	0.10	0.05	0.71	0.22

Years with no retirements in that category are marked with '-'. Values in columns show the share of all retirements in that year relative to the other two categories (i.e. removal, mixed etc.). Values in the total columns show the share of all retirements in that category during 2020-23 relative to the other two categories. Some volumes shown in total columns may not match volumes in individual years due to rounding of decimal places.

Table S4. Share of credits retired by company and by registry

Company	Registry share (%)		
	CDM	GS	VCS
Shell	0.59	2.95	96.46
Delta	24.59	–	75.41
Volkswagen	0.00	5.78	94.22
Banco BV	97.57	–	2.43
Eni	14.21	–	85.79
Telstra	19.67	3.27	77.06
Audi	–	1.25	98.75
Takeda	21.32	15.25	63.43
Sasol	72.41	–	27.59
DPD	–	–	100.00
Boeing	–	5.48	94.52
Chevron	40.21	–	59.79
Gucci	–	–	100.00
PetroChina	1.25	–	98.75
easyJet	–	31.41	68.59
EY	–	16.24	83.76
Norwegian CL	–	0.01	99.99
Yamato	–	–	100.00
Hu-Chems	100.00	–	–
Skoda	–	46.44	53.56
All companies	19.69	3.85	76.47

Registries with no retirements are marked with ‘–’.

	Vintage year																
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Shell			8.8		21.8	0.9	7.6	10.9	7.2	17.3	9.5	10.8	1.6	0.5	0.8	2.6	
Delta					11.3	0.5	2.4	6.4	11.7	18.0	28.8	6.6	3.3	6.9	3.3	0.8	
Volkswagen											1.0	8.2	26.3	30.9	15.8	17.8	
Banco BV								1.5	18.0	8.8		40.3	30.6				0.8
Eni								12.7		3.3	6.9	12.8	16.8	24.6	22.8		
Telstra								0.5	5.2	3.6	1.0	4.4	23.2	23.7	26.1	12.2	
Audi								0.2	0.7	0.2	0.2	0.3	28.7	21.4	25.1	23.4	
Takeda											34.2	35.0	16.8	11.1	2.9		
Sasol		2.2	38.0	7.4	1.8	4.2	11.9	19.1	11.5	1.0	1.6	0.8	0.4				
DPD	1.4	27.1				12.7	10.8	2.6	6.6	7.5	8.9	5.5	6.4	7.7	2.6	0.1	
Boeing					1.3	1.3	1.3	3.4	12.4	1.9	1.3	5.3	11.9	36.2	21.5	2.0	
Chevron								0.1	0.7	38.7	40.8	11.2	6.8	1.6			
Gucci								5.5	43.6	13.5		18.7	11.2	7.5			
PetroChina			7.6		48.1		9.4	0.8	13.1			4.2	4.5	5.9	4.5	1.9	
easyJet							7.3	6.2	5.6	11.8	6.9	4.2	11.2	39.9	4.5	2.3	
EY						5.7	0.7	15.0	7.8	6.7	5.8	6.7	13.0	8.5	11.4	17.8	0.9
Norwegian CL						4.5		39.8	38.2	1.6		3.5	5.5	4.2	2.8		
Yamato												2.2	53.1	42.8	1.9		
Hu-Chems*																	
Skoda							3.5	9.0				5.6	13.2	14.6	27.8	10.3	16.0
All companies	0.1	1.0	2.6	0.1	8.1	1.1	3.2	6.6	7.6	9.2	10.4	8.9	12.2	13.9	9.3	5.6	0.4

Fig. S1. Relative share of credits (%) retired by company and by vintage year

Values show the distribution of vintage years (i.e. the year that an emissions reduction activity occurred) for all credits sourced by a company over 2020-23. For example, 21.8% of credits retired by Shell had a vintage year of 2010. Darker colors indicator higher shares. Data excludes credits retired from CDM since this registry does not disclose vintage years. *One company (Hu-Chems) has no credits recorded because it retired all of its credits from CDM.

	Age of credit vintage at time of retirement (years)																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Shell			2.8	0.8	2.7	0.8	10.5	13.4	20.5	8.1	11.7	4.7	6.9	17.2	<0.1	<0.1	
Delta	0.3	1.5	2.5	8.2	8.4	14.8	29.4	10.3	9.1	3.5	0.7	11.3					
Volkswagen		16.6	32.3	21.3	11.8	16.5	0.5	1.0									
Banco BV			0.8	30.6	40.3		8.8	18.0	1.5								
Eni		1.6	22.2	41.8	14.1	7.6			1.4	0.4	10.9						
Telstra	0.4	23.8	33.6	29.0	3.2	4.3	5.3	0.5									
Audi		2.2	48.0	38.4	8.2	2.4	0.2	0.0	0.6	<0.1	0.1						
Takeda	2.3	6.0	15.3	34.8	40.5	1.3											
Sasol				0.4	0.7	1.6	1.0	11.5	19.1	11.9	4.2	5.1	9.1	33.0	2.2		
DPD		0.1	2.6	8.0	9.5	7.9	12.4	7.0	9.8	7.0	2.9	4.2		6.5	6.8	13.8	1.4
Boeing	0.7	14.3	11.5	31.4	20.4	1.9	12.4	3.4	1.3	1.3	1.3						
Chevron			0.1	1.5	24.9	72.7	0.7		0.1								
Gucci		7.5	7.5	15.0	7.5	1.5	10.5	29.8	20.8								
PetroChina		1.0	4.5	6.0	5.2	0.1	4.2	10.6	1.5	5.7	4.5	13.4	7.8	35.5			
easyJet			4.4	41.9	8.1	5.2	9.5	6.3	11.1	6.2	7.3						
EY		3.3	27.7	13.1	6.6	6.0	5.0	21.7	2.2	13.7	0.7						
Norwegian CL				3.4	6.0	5.9	0.6	0.4	22.0	41.8	15.5	2.0	2.4				
Yamato				1.9	42.8	53.1	2.2										
Hu-Chems*																	
Skoda		25.2	38.9	4.7		13.2	5.6			9.0	3.5						
All companies	0.2	5.2	14.1	16.0	10.1	9.0	9.4	7.2	8.2	4.6	4.4	3.5	1.9	5.4	0.3	0.5	0.1

Fig. S2. Relative share of credits (%) retired by company and by age of vintage at time of retirement

Values show the distribution of the age of vintage years for all credits sourced by a company over 2020-23. For example, 20.5% of the credits retired by Shell had a vintage aged eight years at the time of retirement. Darker colors indicator higher shares. Data excludes credits retired from CDM since this registry does not disclose vintage years. *One company (Hu-Chems) has no credits recorded because it retired all of its credits from CDM.

	Project start year																			
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
Shell	-	-	-	-	-	31.8	0.7	51.2		7.1		4.2	<0.1	1.3	0.3	0.1	0.1	3.2	-	
Delta	0.1	0.1	0.1	0.4	2.5	12.3	2.9	26.2	9.0	6.4	16.8	2.3	12.3	3.9	4.0	0.4	-	-	-	
Volkswagen	-	-	-	0.8	-	-	15.5	13.2	14.6	1.2	-	-	1.5	2.7	24.4	21.4	4.7	-	-	
Banco BV		33.0				1.9		1.9	4.4	1.8		3.2	53.6	<0.1	0.3					
Eni			4.8			1.5	13.2		2.2		5.6		55.6		17.1					
Telstra				0.4	<0.1	<0.1		3.4		17.6	9.1		0.4	5.8	63.4					
Audi				1.8	0.8	0.1	34.1	10.3	0.5	0.4	0.2		10.7	6.5	30.4	4.2	0.1			
Takeda		0.3			1.8	3.2	27.5	33.1	2.6	9.1	3.7	2.9	4.0	1.9	7.7	2.0	0.2			
Sasol				0.1	70.3	13.6	0.6	<0.1		9.1	6.4									
DPD				14.1	20.3	15.4	17.0	8.8	11.2	7.3		2.6	3.4							
Boeing								1.5	0.1	1.6	40.6	14.1	2.6	38.5		1.0				
Chevron									88.0		12.0									
Gucci				3.9		2.1	13.8	20.6	10.0	1.8	6.9	0.4	9.2	1.6	8.5	11.5	8.2	1.3		
PetroChina					1.0	15.8		49.2			1.2	13.2			6.9	10.9		1.8		
easyJet				13.5				5.9		1.8	7.0	11.0	5.0	20.9	24.7		5.5	4.8		
EY				23.4		4.1	12.4	5.7	15.3			8.5	1.8	3.7	4.7	4.2	2.0	14.4		
Norwegian CL				29.7	<0.1		2.0	11.2	1.9	2.0	47.7	5.4		<0.1						
Yamato							3.9	0.0	1.1	0.4			<0.1	1.7	82.1	5.8	5.0			
Hu-Chems					79.6						20.4									
Skoda						2.4		11.2	20.8				14.0		7.6		13.1	14.1	16.8	
All companies	<0.1	2.4	0.3	2.0	4.9	9.6	7.0	19.7	6.9	4.7	7.2	2.7	11.4	3.5	12.1	2.9	1.1	1.3	0.3	

Fig. S3. Relative share of credits (%) retired by company and by project start year

Values show the distribution of project start years (i.e. the year a project began issuing credits, measured by the first year of the first crediting period) for all credits sourced by a company over 2020-23. For example, 51.2% of credits retired by Shell came from offset projects that began issuing credits in 2010. Darker colors indicator higher shares. Data excludes credits retired from CDM since this registry does not disclose vintage years on its registry. *One company (Hu-Chems) has no credits recorded because it sourced all of its credits from CDM.

Table S5. Mean price estimations (\$) and relative cost category by project type

	2020	Relative cost	2021	Relative cost	2022	Relative cost	2023	Relative cost
Removal								
Forestry and land use	7.90	●●●●●	7.97	●●●●●	11.79	●●●●●	15.60	●●●●●
Avoidance								
Agriculture	10.30	●●●●●	9.65	●●●●●	11.02	●●●●●	6.43	●●●
Chemical processes	2.15	●●	3.12	●●	5.14	●	4.69	●●
Forestry and land use	5.40	●●●●●	5.15	●●●●●	10.26	●●●●●	10.84	●●●●●
Household and community	4.34	●●●	5.36	●●●	8.55	●●●	7.33	●●●
Industrial and commercial	0.98	●	2.16	●	5.39	●●	3.69	●
Renewable energy	1.08	●	2.16	●	4.16	●	3.97	●
Waste management	2.69	●●●	3.63	●●●	7.23	●●●	9.00	●●●●

Pricing categories are assigned codes based on the price quintile in which each credit type fell. Dots indicate each quintile as follows: ●= 1st quintile (lowest); ●●= 2nd quintile (mid-low); ●●●= 3rd quintile (average); ●●●●= 4th quintile (mid-high); ●●●●●= 5th quintile (highest). Price estimates data were obtained from Ecosystem Marketplace⁵. Due to a slight inconsistency in the offset project categories used by Ecosystem Marketplace and the Berkeley Carbon Trading Project, here we show prices for projects categorised by Ecosystem Marketplace as 'Energy efficiency and fuel switching' in the *Industrial and commercial* category.

	2023					2022				
	Q1	Q2	Q3	Q4	Q5	Q1	Q2	Q3	Q4	Q5
	Low	Mid-low	Average	Mid-high	High	Low	Mid-low	Average	Mid-high	High
Shell	8.7		0.8		90.4				93.3	6.7
Delta	86.0				14.0	42.8	52.7	2.8	1.5	0.2
Volkswagen	36.7				63.3	64.3			35.2	0.5
Banco BV	0.2		99.8			83.4		16.6		
Eni					100.0	6.7			93.3	
Telstra	100.0				<0.1	100.0				
Audi	50.5				49.5	69.9			2.5	27.7
Takeda	<0.1				100.0	90.7			9.3	
Sasol						100.0				
DPD						83.8		16.2		
Boeing	20.8	47.2			32.0	100.0				
Chevron	100.0					72.6		6.1	21.3	
Gucci									100.0	
PetroChina	2.7	4.7			92.6	4.5			40.6	55.0
easyJet			71.6		28.4	59.0		24.7		16.3
EY	73.2		5.4		21.4	59.2		7.0	33.5	0.3
Norwegian CL	57.1	42.9			<0.1	48.1	51.9			<0.1
Yamato	95.0		5.0							
Hu-Chems										
Skoda	77.4				22.6	52.7			47.3	
All companies	32.9	3.7	4.3		59.1	51.8	14.0	4.4	26.0	3.8

	2021					2020				
	Q1	Q2	Q3	Q4	Q5	Q1	Q2	Q3	Q4	Q5
	Low	Mid-low	Average	Mid-high	High	Low	Mid-low	Average	Mid-high	High
Shell	3.0		87.7	0.9	8.5				93.9	6.1
Delta	29.5		70.3		0.3	87.7			11.9	0.4
Volkswagen	14.0		77.0		9.0	17.8			82.2	
Banco BV	47.8		48.8		3.4					
Eni	44.3		55.7						100.0	
Telstra	100.0		<0.1			100.0				
Audi	5.3		94.7			10.4		89.6		
Takeda			84.0	5.6	10.4	49.7		9.5	40.8	
Sasol	10.8	87.0	2.2			13.7	86.3			
DPD	77.3		22.7			75.7		24.3		
Boeing	74.6		17.4	3.1	4.9	78.2		3.6	7.5	10.7
Chevron	49.4		50.4		0.2				100.0	
Gucci			100.0						100.0	
PetroChina			70.0		30.0					
easyJet										
EY	11.3		75.3		13.4	19.6			80.4	
Norwegian CL	99.8			0.1	<0.1					
Yamato										
Hu-Chems		100.0					100.0			
Skoda	65.3		34.7							
All companies	30.4	6.0	60.0	0.2	3.4	39.4	12.1	3.6	43.5	1.4

Fig. S4. Share of credits (%) retired by price category by year

The relative share of credits retired by each company, organised into five quintiles. Each reflects the average estimated price of eight types of offset projects contained in our database relative to the price of other offset types (see Table S5). Price estimates data were obtained from Ecosystem Marketplace⁵.

	Vintage year																
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Removal																	
Forestry and land use					1.5	8.3	7.6	5.0	39.6			6.9	5.5	8.7	11.2	5.6	
Avoidance																	
Agriculture								0.6					25.7	29.8	26.1	17.7	
Chemical processes		2.9	50.6	3.7	2.4	5.7	15.8	0.7	14.3	0.9	1.9	1.0					
Forestry and land use			3.9		14.6	0.3	4.3	8.9	6.5	12.5	9.6	11.1	11.7	11.1	4.8	0.5	
Household and community							2.7	1.9	1.7	24.8	12.9	20.2	15.1	12.0	4.7	2.2	1.8
Industrial and commercial								9.3	20.6	11.0	40.5	1.1	1.0	8.2	8.1	0.2	
Renewable energy	0.2	0.8		0.1		1.8	1.4	3.0	3.8	4.2	6.5	7.1	16.4	20.7	17.3	15.7	1.1
Waste management		53.3		1.1				0.5	7.8	1.0	17.9	0.7	4.0	10.4	3.1		

Fig. S5. Relative share of credits (%) retired in each project category by vintage year

Values show the distribution of vintage years (i.e. the year that an emissions reduction activity occurred) for all credits sourced by all twenty companies over 2020-23. Results show that, for example, 50.6% of credits sourced from offset projects in the *Chemical processes* category had a vintage year of 2008. Data excludes credits retired from CDM since this registry does not disclose vintage years. Darker colors indicator higher shares.

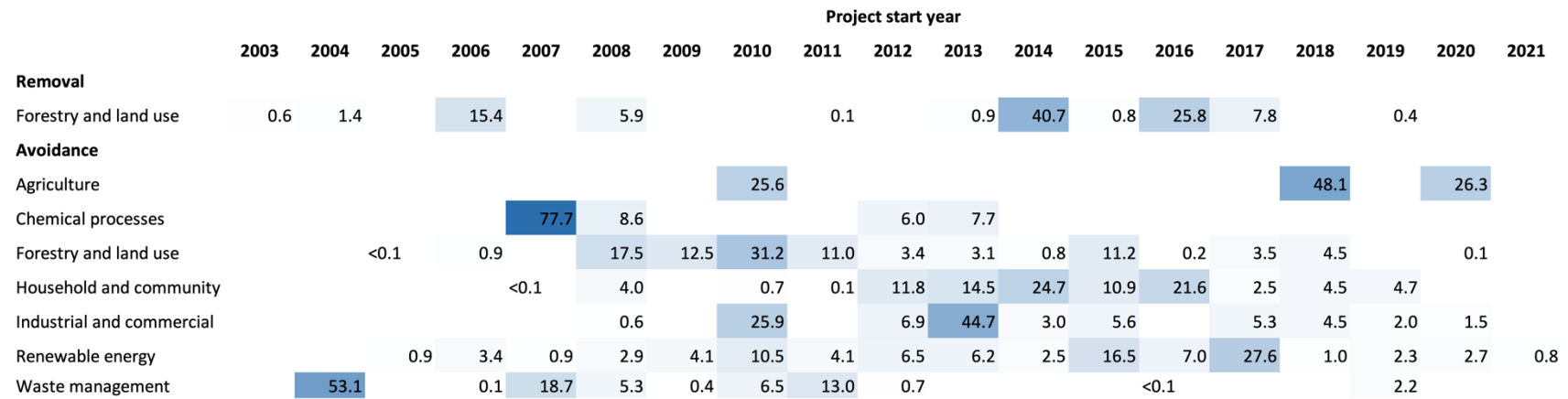


Fig. S6. Relative share of credits (%) retired in each project category by project start year

Values show the distribution of project start years (i.e. the year a project began issuing credits, measured by the first year of the first crediting period) for all credits sourced by all twenty companies over 2020-23. For example, 77.7% of credits in the *Chemical processes* category came from offset projects that began issuing credits in 2007. Darker colors indicator higher shares.

Table S6. Absolute share (%) of retirement volumes by offset type

	Q1	Q2	Q3	Q4	Q5
Quintile lowest value (t CO ₂ e)	Min	2,750	8,354	25,000	77,192
Quintile highest value (t CO ₂ e)	2,750	8,354	25,000	77,192	Max
Removal					
Forestry and land use	0.02	0.04	0.31	1.00	1.15
Avoidance					
Agriculture	0.00	0.01	0.02	0.41	0.09
Chemical processes	0.01	0.10	0.13	0.31	4.27
Forestry and land use	0.10	0.35	1.14	3.83	38.43
Household and community	0.01	0.15	0.30	0.25	0.22
Industrial and commercial	0.01	0.03	0.16	0.87	5.67
Renewable energy	0.08	0.35	2.16	6.26	27.27
Waste management	0.01	0.03	0.13	0.16	4.15

The absolute share (%) of retirement volumes by offset type, organised into quintiles. Results show that 38.43% of all credits retired came from *Forestry and land-use projects* (avoidance) projects and were obtained in transactions sized 77,192 tCO₂e or higher.

Table S7. Relative share (%) of all renewable energy credits retired by country

Country	Solar (C)	Solar (D)	Wind	Geo	Biomass	Hydro	Bundled	Total
Brazil	0.00	0.00	2.85	0.00	4.61	7.15	0.00	14.61
Bulgaria	0.00	0.00	0.23	0.00	0.13	0.00	0.00	0.36
Chile	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.21
China	0.08	0.08	8.93	2.29	2.11	2.08	0.00	15.58
Colombia	0.00	0.00	0.00	0.00	0.00	2.85	0.00	2.85
Dominican R.	0.00	0.00	1.10	0.00	0.00	0.00	0.00	1.10
El Salvador	0.00	0.00	0.00	0.71	0.00	0.00	0.00	0.71
Guatemala	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.42
India	28.48	3.22	21.35	0.00	0.02	0.74	0.44	54.25
Indonesia	0.00	0.00	0.07	0.44	0.00	0.62	0.00	1.13
Jamaica	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.17
Mauritania	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.02
Mauritius	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Namibia	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Nicaragua	0.00	0.00	1.30	0.07	0.00	0.00	0.00	1.37
Pakistan	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.29
Philippines	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.19
South Korea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Africa	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.08
Taiwan	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.35
Thailand	0.00	0.00	0.10	0.00	0.62	0.00	0.00	0.72
Turkey	0.00	0.00	2.42	0.00	0.00	2.09	0.00	4.51
Uganda	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.20
United States	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.10
Uruguay	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.03
Vietnam	0.68	0.00	0.00	0.00	0.00	0.02	0.00	0.70
All countries	29.49	3.30	39.74	3.50	7.78	15.74	0.44	100.00

Solar (C) = centralized. Solar (D) = distributed. Geo = geothermal. Table shows the relative volume of renewable energy credits retired by all twenty companies from each country. For example, 4.61% of all renewable energy credits came from biomass projects based on Brazil.

Project start year (start of first crediting period)

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total	Meet criteria	Share (%)	
Brazil																					
Solar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Wind	0	0	0	0	0	0	0	0	0	369,500	0	501,007	510,682	0	0	0	0	1,381,189	0	0.00	
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	
Biomass	0	0	2,757	0	0	0	0	0	0	0	2,200,000	0	30,000	0	0	0	0	2,232,757	0	0.00	
Hydro	0	472,882	0	0	0	17	0	0	0	0	2,989,398	0	0	0	0	0	0	3,462,297	0	0.00	
																		7,076,243	0	0.00	
Bulgaria																					
Solar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	
Wind	0	0	0	0	0	0	0	110,000	0	0	0	0	0	0	0	0	0	110,000	0	0.00	
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	
Biomass	0	0	0	0	0	0	0	0	64,693	0	0	0	0	0	0	0	0	64,693	0	0.00	
Hydro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	
																		174,693	0	0.00	
China																					
Solar	0	0	0	0	0	0	0	0	80,037	0	0	0	0	0	0	0	0	80,037	0	0.00	
Wind	0	0	0	0	949,031	2,452,684	557,555	0	176,508	0	189,905	0	0	0	0	0	0	4,325,683	949,031	21.94	
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	704,007	407,822	1,111,829	0	0.00	
Biomass	125,679	0	0	0	0	4,405	206,154	70,000	0	0	0	0	0	0	1,000	614,192	0	1,021,430	125,679	12.30	
Hydro	0	483,549	32,098	0	0	0	0	0	491,675	0	0	0	0	0	0	0	0	1,007,322	0	0.00	
																		7,546,301	1,074,710	14.24	
Colombia																					
Solar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	
Wind	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	
Biomass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	
Hydro	0	0	0	0	0	0	0	53,225	0	0	5,300	1,322,732	0	0	0	0	0	1,381,257	0	0.00	
																		1,381,257	0	0.00	
Dominican R.																					
Solar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	
Wind	0	0	0	0	0	0	0	0	534,806	0	0	0	0	0	0	0	0	534,806	0	0.00	
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	
Biomass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	
Hydro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	
																		534,806	0	0.00	

El Salvador	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total	Meet criteria	Share (%)
Solar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Wind	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Geothermal	0	0	342,500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	342,500	0	0.00
Biomass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Hydro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
																		342,500	0	0.00
Guatemala	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total	Meet criteria	Share (%)
Solar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Wind	0	0	0	0	0	0	0	0	0	0	203,000	0	0	0	0	0	0	203,000	203,000	100.00
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Biomass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Hydro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
																		203,000	203,000	100.00
India	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total	Meet criteria	Share (%)
Solar	0	0	0	0	0	0	0	0	68,000	0	1,629,204	898,049	12,283,580	218,564	260,120	0	0	15,357,517	14,878,833	96.88
Wind	0	157,515	78,408	1,286,374	678,882	1,440,662	1,093,431	2,464,679	1,321,474	362,685	320,599	247,980	253,713	129,405	508,357	0	0	10,344,164	235,923	2.28
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Biomass	0	0	0	0	9,051	0	0	0	0	0	0	0	0	0	0	0	0	9,051	9,051	100.00
Hydro	0	28,753	0	0	0	150,000	0	0	94,000	83,891	0	0	0	0	0	0	0	356,644	0	0.00
																		26,067,376	15,123,807	58.02
Indonesia	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total	Meet criteria	Share (%)
Solar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Wind	0	0	0	0	0	0	0	35,000	0	0	0	0	0	0	0	0	0	35,000	35,000	100.00
Geothermal	0	211,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	211,000	211,000	100.00
Biomass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Hydro	0	302,240	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	302,240	0	0.00
																		548,240	246,000	44.87
Jamacia	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total	Meet criteria	Share (%)
Solar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Wind	0	0	0	0	0	0	0	83,946	0	0	0	0	0	0	0	0	0	83,946	0	0.00
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Biomass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Hydro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
																		83,946	0	0.00

Mauritania	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total	Meet criteria	Share (%)
Solar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Wind	0	0	0	0	0	0	0	0	0	0	0	10,000	0	0	0	0	0	10,000	0	0.00
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Biomass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Hydro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
																		10,000	0	0.00
Namibia	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total	Meet criteria	Share (%)
Solar	0	0	0	0	0	0	0	0	0	0	0	0	25,000	0	0	0	0	25,000	0	0.00
Wind	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Biomass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Hydro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
																		25,000	0	0.00
Nicaragua	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total	Meet criteria	Share (%)
Solar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Wind	0	0	0	0	0	529,000	0	100,000	0	0	0	0	0	0	0	0	0	629,000	0	0.00
Geothermal	32,500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32,500	32,500	100.00
Biomass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Hydro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
																		661,500	32,500	4.91
Pakistan	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total	Meet criteria	Share (%)
Solar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Wind	0	0	0	0	0	0	0	0	141,433	0	0	0	0	0	0	0	0	141,433	141,433	100.00
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Biomass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Hydro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
																		141,433	141,433	100.00
Philippines	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total	Meet criteria	Share (%)
Solar	0	0	0	0	0	0	0	0	0	0	0	92,338	0	0	0	0	0	92,338	92,338	100.00
Wind	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Biomass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Hydro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
																		92,338	92,338	100.00

Thailand	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total	Meet criteria	Share (%)
Solar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Wind	0	0	0	0	0	0	0	0	0	0	0	0	0	30,479	19,521	0	0	50,000	0	0.00
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Biomass	300,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	300,000	300,000	100.00
Hydro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
																		350,000	300,000	85.71

Uganda	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total	Meet criteria	Share (%)
Solar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Wind	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Biomass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Hydro	0	0	0	0	96000	0	0	0	0	0	0	0	0	0	0	0	0	96,000	0	0.00
																		96,000	0	0.00

Uruguay	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total	Meet criteria	Share (%)
Solar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Wind	0	0	0	0	0	0	0	0	0	49,367	0	0	0	0	0	0	0	49,367	0	0.00
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Biomass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Hydro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
																		49,367	0	0.00

Vietnam	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total	Meet criteria	Share (%)
Solar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	330,316	0	0	330,316	0	0.00
Wind	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Biomass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Hydro	0	0	0	0	0	0	8,325	0	0	0	0	0	0	0	0	0	0	8,325	0	0.00
																		338,641	0	0.00

Fig. S7. Application of registry additionality criteria for renewable energy credits (tCO₂e) by country and technology

Tables show the volume of credits that meet additionality criteria set by GS⁶, which require that renewable energy activities seeking registration as an offset project occur in a low-income or lower-middle income country where the penetration level of that energy technology is <5% of all grid-installed capacity. Data for country classifications and renewable energy penetration from World Bank⁷ and IRENA⁸. 213,465 tCO₂e of retirements from the ‘bundled renewables’ category in India are excluded because no corresponding classification exists in the IRENA data. Years during 2005-2021 reflect the start year for all renewable energy projects in the dataset. Years when a country is classified as a low-income or lower-middle income country are highlighted in light green in top row. All years with a penetration rate below 5% for each renewable energy technology are marked in light green. Years satisfying both criteria are marked in dark green and marked by a dark border. Years not meeting any criteria appear in white. Results for seven countries (Chile, Mauritius, South Africa, South Korea, Taiwan, Turkey, United States) are not shown because they were not classified as Low-income or Lower-middle income country during the period 2005-2021 and thus do not meet additionality criteria.

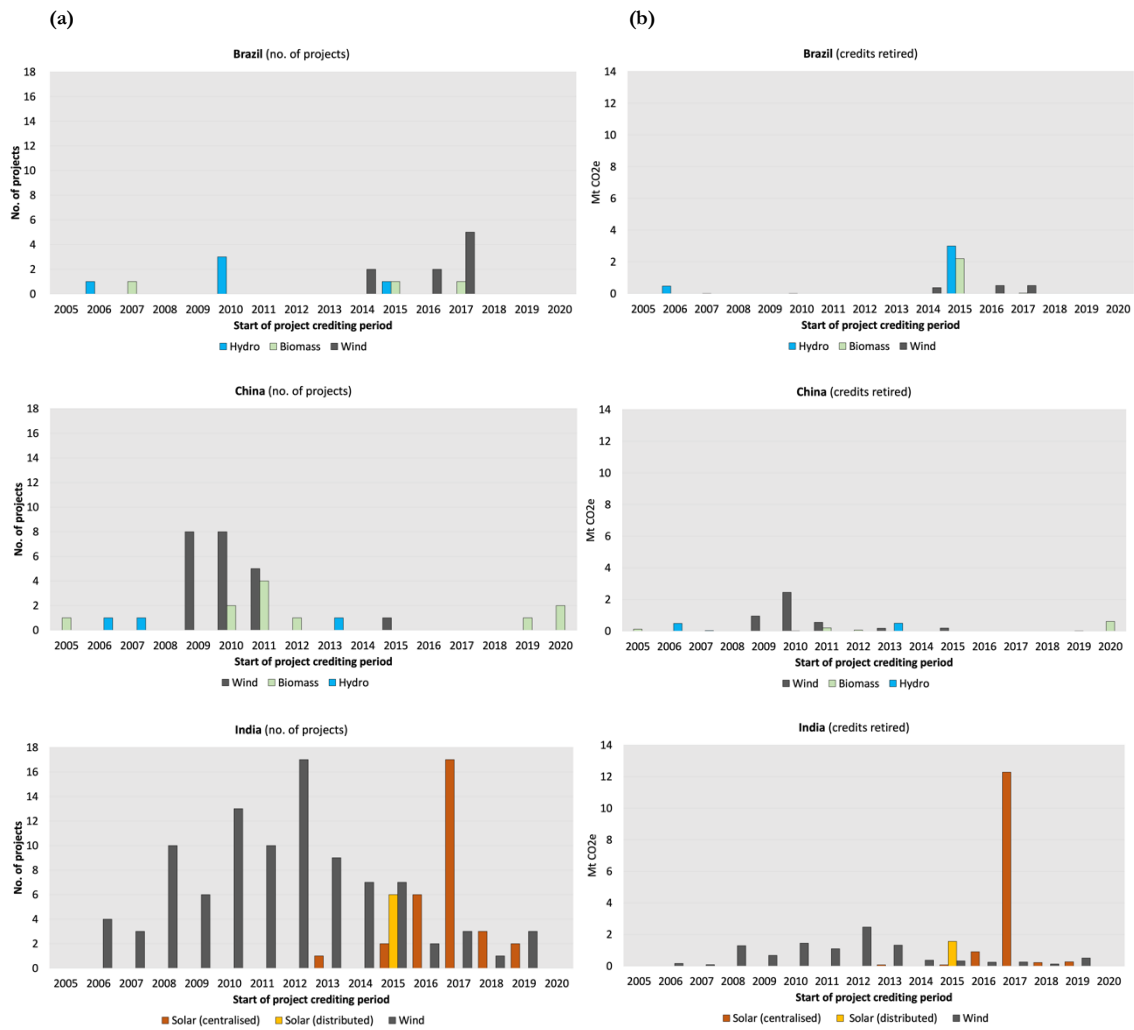


Fig. S8. Renewable energy projects and credits retired in India, Brazil and China

a) Number and type of renewable energy projects from which offset credits were retired in the three countries making up 84.4% of renewable energy retirements in the dataset. The x-axes reflect the distribution of project start dates, based on the first year that a project began to issue credits (i.e. the start of the first crediting issuance period). b) Absolute volume of offset credits retired from the same projects in the same three countries.

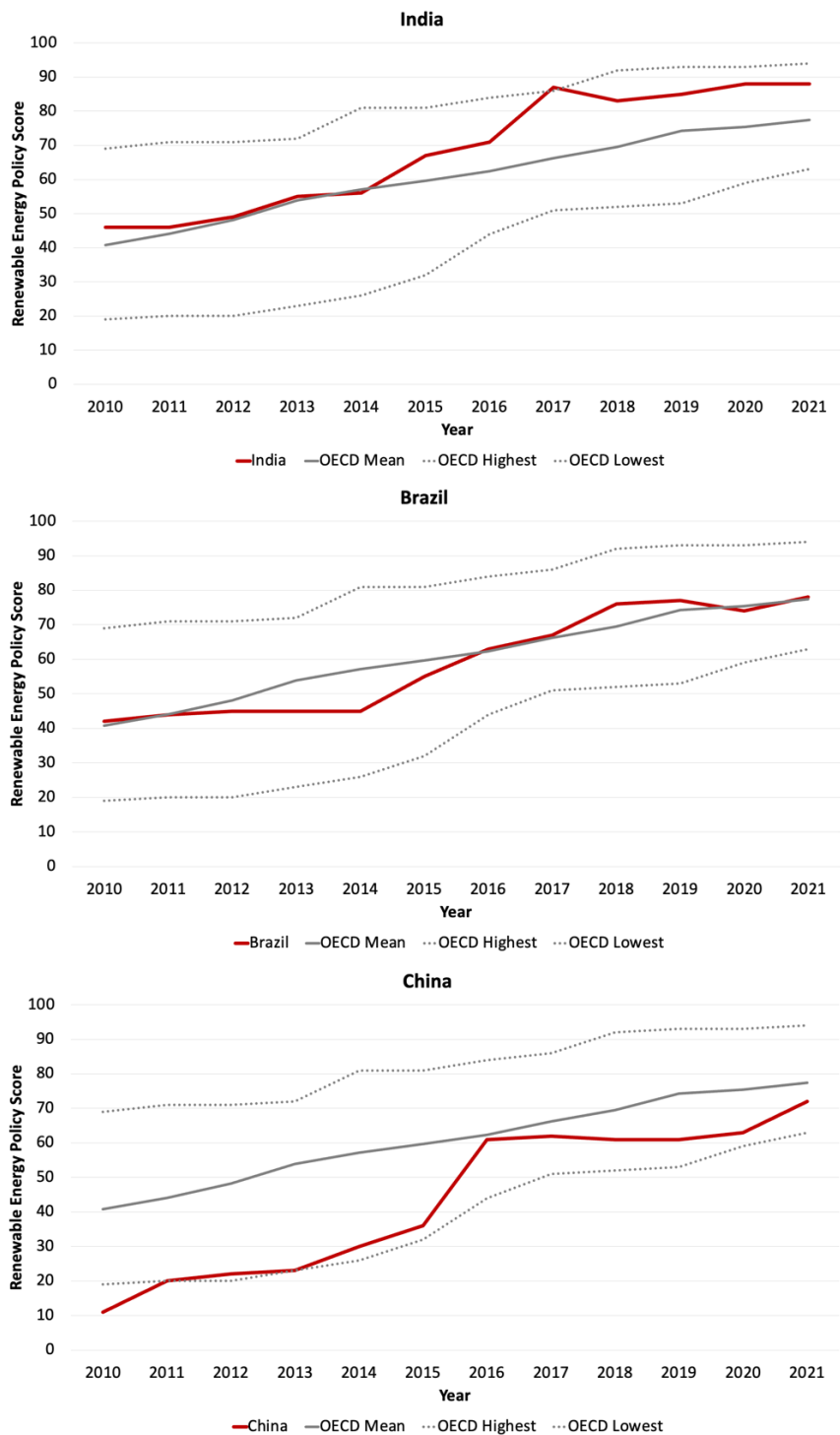


Fig. S9. Supplementary policy analysis for top three offset-project countries

Annual scores for Regulatory Indicators for Sustainable Energy (RISE) from World Bank⁹ for the three countries supplying 84% of renewable energy credits used by the twenty companies. Figures show total scores for all seven indicators in RISE’s ‘renewable energy’ category. Scores for high-income OECD nations are shown for reference. To compute the mean score of OECD nations, we weighted the yearly score of each member nation by its population relative to the entire OECD in that year, and then tallied the scores. This analysis assumes that projects starting their credit issuing period during a time of supportive government policy would constitute a weak argument for additionality (see Fig. S7).

References

1. CDM. *CDM Registry*. 2024 [cited 2024 February 10]; Available from: <https://cdm.unfccc.int/Registry/index.html>.
2. Gold Standard. *Gold Standard Foundation Registry*. 2024 [cited 2024 February 10]; Available from: <https://registry.goldstandard.org/projects?q=&page=1>.
3. Verified Carbon Standard. *Verra Search Page*. 2024 [cited 2024 February 10]; Available from: <https://registry.verra.org/app/search/VCS/All%20Projects>.
4. Net Zero Tracker. *Data Explorer*. 2023 [cited 2023 October 10]; Available from: <https://zerotracker.net>.
5. Ecosystem Marketplace. *EM Reports and Resources on Global Carbon Markets*. 2023 [cited 2023 August 1]; Available from: <https://www.ecosystemmarketplace.com/carbon-markets/>.
6. Gold Standard. *Renewable Energy Requirements Version 1.4*. 2021 [cited 2023 October 10]; Available from: https://globalgoals.goldstandard.org/standards/202_V1.4_AR-Renewable-Energy-Activity-Requirements.pdf.
7. World Bank. *World Bank Country and Lending Groups*. 2023 [cited 2023 October 10]; Available from: <https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups>.
8. IRENA. *Renewable Capacity Statistics*. 2023 [cited 2023 August 25]; Available from: https://pxweb.irena.org/pxweb/en/IRENASTAT/IRENASTAT_Power%20Capacity%20and%20Generation/RESHARE_2023_cycle2.px/.
9. World Bank Group. *Regulatory Indicators for Sustainable Energy (RISE)*. 2023 [cited 2023 August 30]; Available from: <https://rise.esmap.org/reports>.