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Availability of offsets for a global market-based mechanism for international aviation

Briefing paper

Berlin, 22/10/2015

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Summary

At its 37th Assembly, the International Civil Aviation Organization (ICAO) agreed a global aspirational goal of Carbon Neutral Growth by 2020 (CNG 2020). In 2013, ICAO established working groups for developing a Global Market-Based Mechanism (GMBM) to achieve this goal. According to its work program, the mechanism should be adopted in 2016 and come into force in 2020. The first period of the GMBM is planned to run from 2021 to 2035.

During the development of the GMBM it has been questioned whether there will be enough offset unit supply to cover ICAO's demand. So far the CDM has been the largest source of credits for offsetting greenhouse gas (GHG) emissions: More than 7,500 projects had been registered by 30/08/2015. Based on the CDM project pipeline it is therefore analysed in the following whether the CDM could provide sufficient offsets to cover the demand stemming from the GMBM for international aviation and whether this would still be the case if eligibility criteria for certain project types were introduced to address concerns towards environmental integrity.

The results of this analysis support that credits from the pipeline of existing CDM projects could cover this demand for a period of at least eight years even if eligibility requirements for certain project types and vintages are introduced. If, in addition, the four years from ICAO's potential decision to establish the GMBM in late 2016 to its entrance into force in early 2021 are taken into account, the period amounts to 12 years, which is certainly long enough to provide CDM project developers sufficient lead time to develop and register new CDM projects. Based on this evidence, concerns that there is a scarcity of offset supply for ICAO's GMBM would seem to be groundless even if ICAO were to deem only credits with high environmental quality standards eligible and to use only recent vintages.

1. Background

At its 37th Assembly, the International Civil Aviation Organization (ICAO 2010) agreed a global aspirational goal of Carbon Neutral Growth by 2020 (CNG 2020). In 2013, ICAO established working groups for developing a Global Market-Based Mechanism (GMBM) to achieve this goal. According to its work program, the mechanism should be adopted in 2016 and come into force in 2020. The first period of the GMBM is planned to run from 2021 to 2035.

The main design elements of the GMBM are being discussed by the ICAO's Environmental Advisory Group (EAG) and by the Global Market-Based Measure Task Force (GMTF) established for developing the GMBM. Within the EAG the core design features are being elaborated while GMTF, an expert group within the Committee on Aviation Environmental Protection (CAEP), has been assigned the task of developing rules for the monitoring, reporting and verification (MRV) of CO_2 emissions and quality and eligibility criteria for offset units.

It is often questioned, particularly by the aviation industry, whether there will be enough offset unit supply to cover ICAO's demand. While other potential sources of offsets exist, the CDM has been the largest source of credits for offsetting GHG emissions up to now: More than 7,500 projects were registered by 30/08/2015. The project pipeline is well documented by UNEP DTU (2015) and IGES (2015). It goes up to the year 2047. For the purposes of this study, the CDM pipeline will be examined in regards to the following research questions:

- Could the CDM alone be enough to meet the offset demand of ICAO's GMBM?
- Would the supply also be sufficient if certain quality restrictions were applied?

In section 2 of the paper the approach and the assumptions used to address these questions are explained. Section 3 includes the analysis and their results while section 4 provides the conclusions which can be drawn from the analysis.

2. Approach

The analysis draws on the CDM project pipelines provided and regularly updated by UNEP DTU (2015) and IGES (2015). Both databases are compiled from data provided in the project design document (PDD) of each CDM project. This data is complemented by information from other sources and the author's own calculations and estimates based on UNEP DTU and IGES. The additional data provided in each of the databases is slightly different: IGES, for example, includes an estimate of the projected yearly CER issuance per project ranging from 2000 to 2047, while UNEP DTU compares projected and actual issuance to calculate an issuance success rate, which was used to adjust the future CER supply potential. Therefore, both databases can be merged to one comprehensive database by referencing to the unique number of each CDM project.

In addition to registered projects, the databases also include projects which are withdrawn, rejected or under validation. However, for this analysis only registered projects are taken into account.

In order to provide a conservative estimate, the yearly supply potential estimated by IGES was adjusted by the project-type specific issuance success rate. For project types for which it was not possible for statistical reasons to determine an issuance success rate, the overall average was applied. On average, actual issuance and thus the adjusted CER supply is about 15 % lower than estimated in the PDDs.

The environmental integrity of certain CDM project types has been called into question in the literature because they are likely to be not additional to what would have happened without the CDM, they provide perverse incentives to increase emissions rather than reducing them, or because their permanence is questionable (Dechezleprêtre et al. 2014, 2014, Gillenwater 2012; Purdon 2014; Schneider 2009; Spalding-Fecher et al. 2012). It is thus suggested that these project types be excluded from the CDM. Without discussing these suggestions in detail, it should here be scrutinised whether the CDM's supply potential would be sufficient for ICAO's demand even if CERs from contentious projects types are excluded. The following projects types were considered contentious for this analysis:

- fossil energy supply;
- hydro (> 20 MW);
- industrial gases (HFC-23, partly N_2O);
- land use, land use change and forestry (LULUCF);
- biomass; and
- wind.

For identifying these projects in the pipeline, the following settings of the joint database were used:

- Scale: large and small[1]

[1] Small scale: renewable energy projects < 15 MW, energy efficiency projects < 60 GWh/y output, other projects < 60 kt CO_2e emission reduction (decision 1/CMP.2, para 28). All projects beyond these thresholds are considered to be large.

- Type: 27 different project types
- Sub-type: 126 different projects sub-types.

Based on these features almost 200 different sub-project types have been identified. They were used to distinguish between those project types which are included and excluded. Small hydro, for example, was included while large hydro is excluded. For N_2O adipic acid projects, which are excluded, are distinguished from other N_2O projects, which are included since their additionality is less. Table 2 in the Annex documents in detail which of the sub-types have been included in or excluded from the estimate of the CDM's supply potential due to their categorisation as "contentious" according to the above-mentioned considerations.

Table 1 provides an overview of the CDM's total adjusted supply potential during the period 2021 to 2035 by project-type and scale and also illustrates which CER volumes would be included or excluded if additional project type-specific eligibility criteria were applied.

Table 1: Potential adjusted CER supply by scale and project type, 2021 to 2035

Project type	Excluded		Included		Total
Scale	Large	Small	Large	Small	
	- CERs in million -				
Afforestation	5,98	0,29			6,27
Agriculture				0,01	0,01
Biomass energy	203,08	56,02			259,10
Cement			3,65		3,65
CO2 usage			0,13		0,13
Coal bed/mine methane			89,52	13,51	103,03
EE households			0,49	1,61	2,10
EE industry			5,41	2,45	7,86
EE own generation			66,29	1,96	68,26
EE service			0,16	1,91	2,07
EE supply side	10,09	0,23	39,82	0,66	50,80
Energy distribution			5,86	0,32	6,18
Fossil fuel switch	199,19			0,94	200,13
Fugitive			49,23		49,23
Geothermal			126,46	0,01	126,47
HFCs	538,99	0,00			538,99
Hydro	2.147,67		1,03	215,64	2.364,34
Landfill gas			191,01	4,65	195,66
Methane avoidance			18,16	58,76	76,92
Mixed renewables			3,98	0,17	4,15
N2O	187,81		180,60		368,42
PFCs and SF6			4,35		4,35
Reforestation	24,49	0,92			25,41
Solar			85,31	22,55	107,86
Tidal			3,08		3,08
Transport			10,44	0,47	10,91
Wind	1.928,81		1,91	25,99	1.956,71
Total	5.246,11	57,46	886,88	351,60	6.542,05

Source: Own calculations based on UNEP DTU (2015), IGES (2015)

Adjusted by the issuance success rate, the CDM could supply a volume of some 6.5 Gt of CERs in the period of 2021 to 2035 overall. The largest volumes stem from hydro, wind and HFCs. However, they are all considered contentious and thus fall, to a large extent, in the category of excluded project types.

To determine whether the potential would be sufficient, it is compared with the expected demand. The estimate of international aviation's offset demand is based on a projection by Lee et al. (2013). It depends, by definition of the GMBM,[2] on the CO_2 emission growth of international aviation, which

[2] Whether the ambition of the GMBM to achieve carbon neutral growth from 2020 is adequate from an environmental perspective can be questioned (Bows-Larkin 2015). However, this question goes beyond the scope of this briefing paper.

amounts to 3-4 %/y. According to this projection, the demand increases from 26 Mt in 2021 to 448 Mt in 2035. Aggregated over the entire period from 2021 to 2035 it amounts to 3.3 Gt.

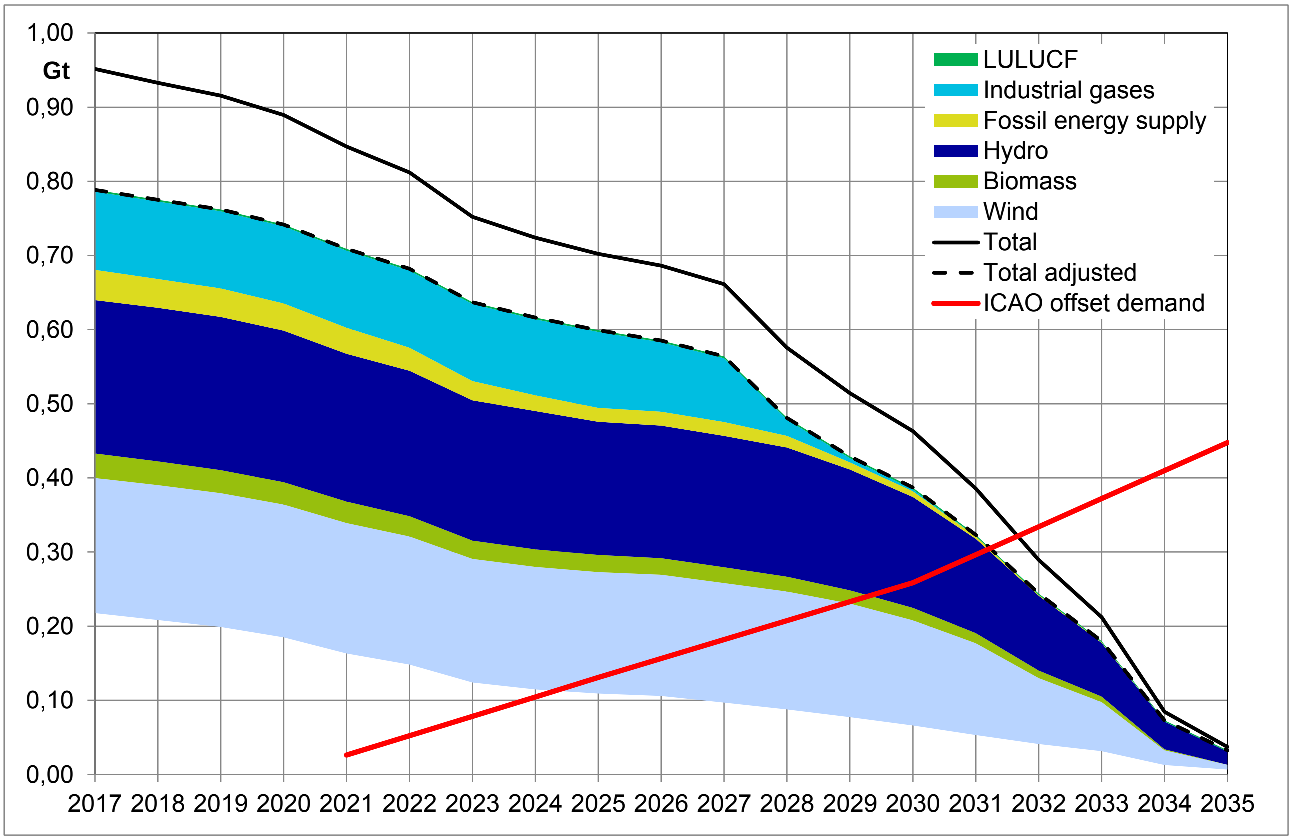
In the next section, different assumptions with regard to supply are applied in order to analyse the circumstances under which the CER supply potential would be sufficient to cover the offset demand of international aviation.

3. Analysis

The following analysis is based on registered projects only. It implicitly assumes that no new CDM projects are developed and registered, but that credits continue to be issued for existing projects. However, this is certainly too conservative. Registration of CDM projects has considerably slowed down from its peak in 2012 due to, among other reasons, considerably declining CER prices. Nevertheless, since 2013 almost 500 new CDM projects have been registered despite low demand for CERs. If ICAO agreed on the GMBM by the end of 2016, it is very likely that project developers would aim at registering new CDM projects to meet the new demand. Estimating the volume of such a new supply would be difficult and highly speculative. However, ignoring new CDM projects entirely is certainly a conservative assumption with regard to the CDM's future offset supply potential.

Figure 1 illustrates the yearly supply and adjusted supply of CERs during the period 2017 to 2035. The CER supply is declining because no new projects are added to the CDM project pipeline. In addition, the offset demand of international aviation is included in the figure (red line). Supply from LULUCF projects is virtually invisible because their share in the supply pipeline is very small (< 1 % both in terms of number of projects and supply potential).

Figure 1: Offset demand and supply, 2017 to 2035

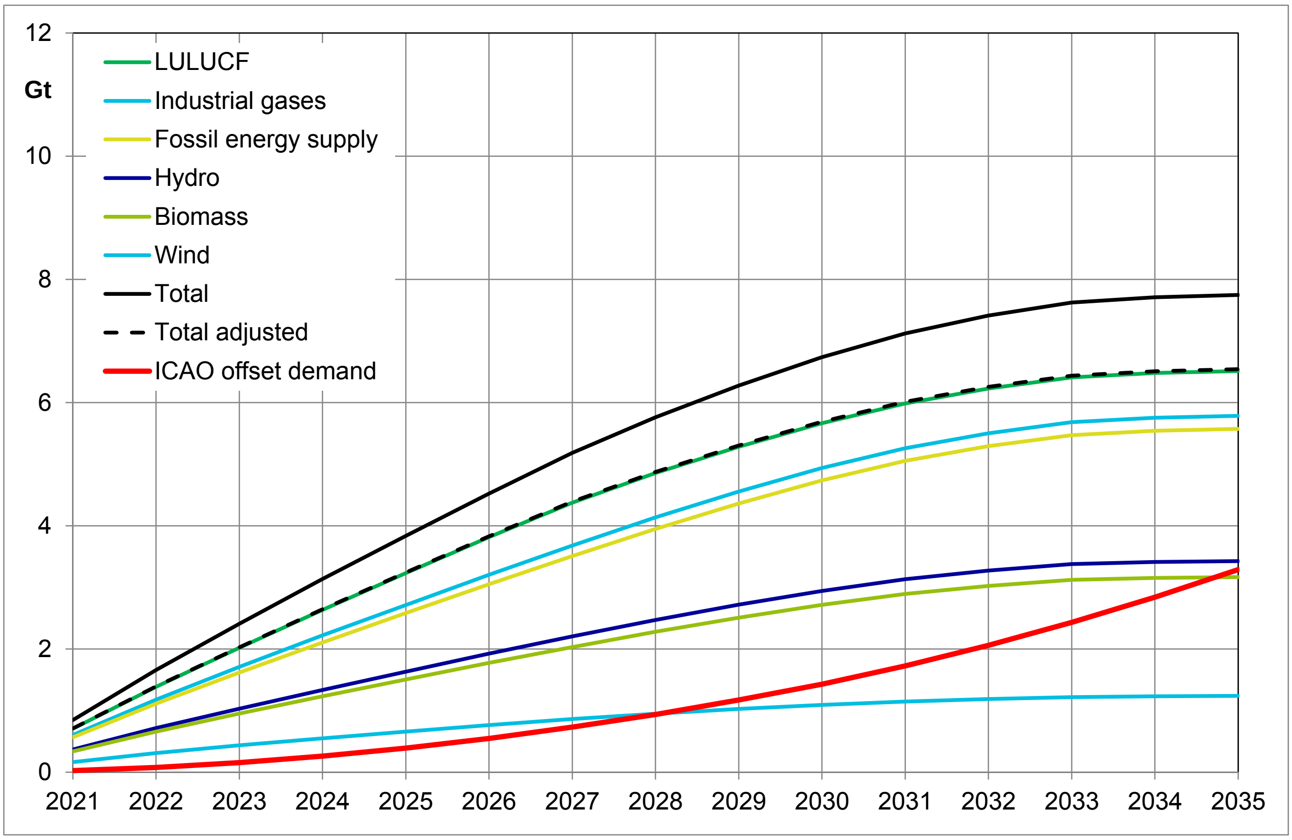


Source: Own calculations based on UNEP DTU (2015), IGES (2015), Lee et al. (2013)

At the start of the GMBM, the adjusted yearly CER supply is much higher than the demand. Only after 10 years would the yearly demand exceed the supply. If all contentious projects qualified as contentious were excluded, the yearly supply would still be higher than demand from international aviation in the first four years.

However, emissions do not have to be offset by units from the same year. Therefore, it is more appropriate to compare accumulated demand and supply. Figure 2 depicts the accumulated supply and demand over the period of 2021 to 2035, including both the original and the adjusted supply estimates. The CER supply flattens towards 2035 because existing projects reach the end of their crediting period while it is assumed that no new projects are registered.

Figure 2: Accumulated offset demand and supply, 2021 to 2035



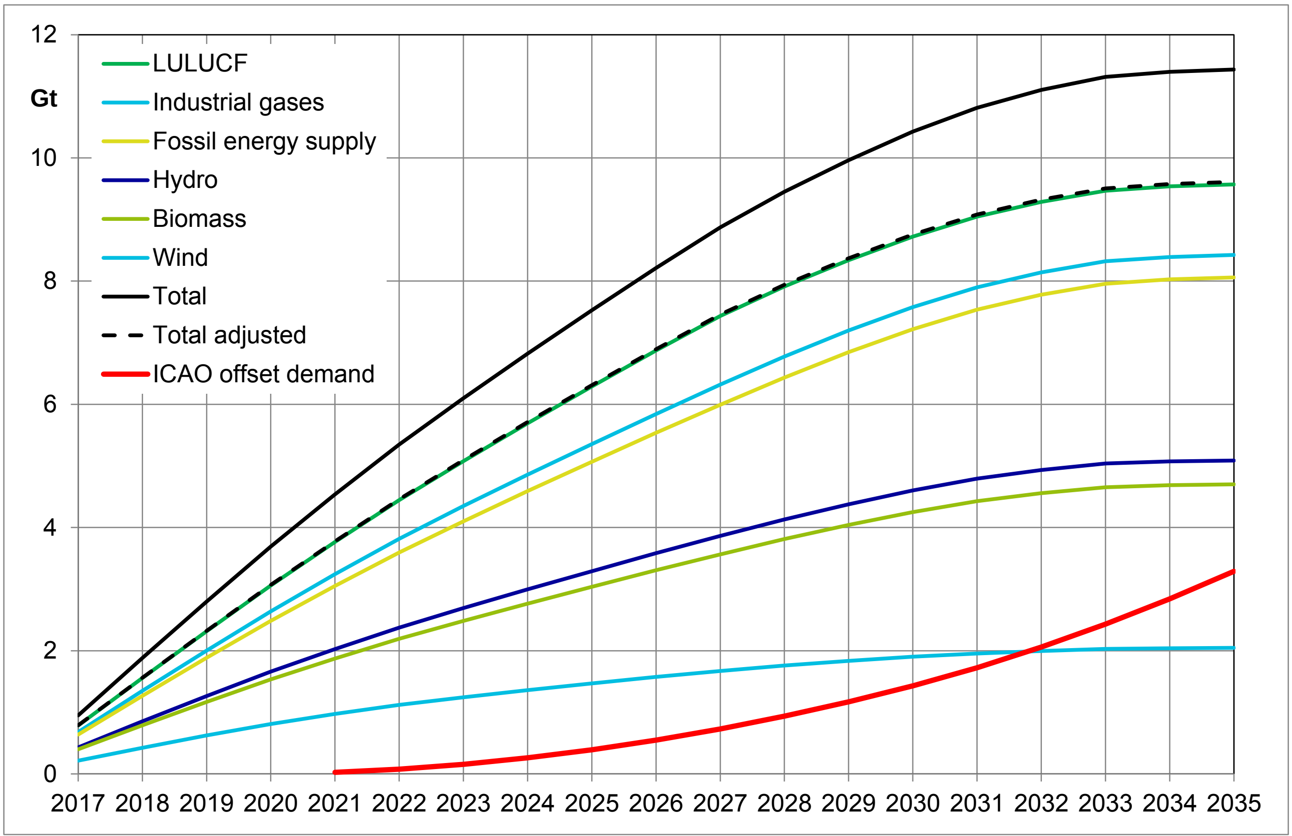
Source: Own calculations based on UNEP DTU (2015), IGES (2015), Lee et al. (2013)

The adjusted CER supply would be about double as high as the demand from international aviation. Even if all contentious project types were excluded, the supply would still be sufficient for eight years. If wind projects were eligible, the CER supply could fully cover the demand even if no new projects are registered.

Another feature which determines the CER supply is the vintage of the CERs. So far it has been assumed that only CERs generated after the start of the GMBM are eligible. Post-2020 credits would be emission reductions generated during the period in which the GMBM is in operation and would contribute as a result to the climate neutral goal. Since the target applies only to post-2020 emissions it can be argued that in order to ensure the consistency of the target only emission reductions achieved post-2020 should be eligible for compliance. Moreover, offsets from pre-2021 years could, under certain circumstances, also lower cumulative emissions reductions if a seller country later on takes a target (Kollmuss et al. 2014). The UNFCCC rules do not include any provisions on how host countries selling CDM offset credits must account for these in their own greenhouse gas targets. The sale of such offsets can lead to double claiming if the host country has a reduction target or pledge that covers the sector under which the CDM project was implemented.

Offsets generated prior to the start of the GMBM therefore involve a higher risk of undermining the environmental integrity of the GMBM. However, if the concerns were appropriately addressed under the UNFCCC through consistent accounting of CERs, including those generated after the ICAO's decision to implement the GMBM, they could also be taken into account. Figure 3 is similar to Figure 2, though it accumulates the CER supply from 2017 onwards, i.e. it is assumed that credits issued after the ICAO's decision to implement the GMBM are eligible.

Figure 3: Accumulated offset demand and supply, 2017 to 2035



Source: Own calculations based on UNEP DTU (2015), IGES (2015), Lee et al. (2013)

Under these assumptions the adjusted supply would be more than three times as high as the offset demand of international aviation. Even if all contentious projects are excluded, the supply would last for more than 10 years. This would certainly provide project developers with enough lead time to develop and register new projects under the CDM.

4. Conclusions

The above analysis takes a pragmatic and conservative approach to answer the questions of whether the CDM could provide sufficient offsets to cover the demand stemming from the GMBM for international aviation and whether this would still be the case if eligibility criteria for certain project types were introduced to address concerns about environmental integrity.

The results of the analysis support the argument that credits from the pipeline of existing CDM projects alone could meet the relevant demand for a period of at least eight years even if eligibility requirements for certain project types and vintages were introduced. If, in addition, the four years from ICAO's potential decision to establish the GMBM in late 2016 to its entrance into force in early 2021 are taken into account, the period amounts to 12 years, which is certainly long enough to provide CDM project developers sufficient lead time to develop and register new CDM projects. Based on this evidence, concerns that there is a scarcity of offset supply for ICAO's GMBM would seem to be groundless, even if ICAO were to deem only credits with high environmental quality standards eligible and to use only recent vintages.

5. List of References

Bows-Larkin A. (2015). All adrift: aviation, shipping, and climate change policy. Climate Policy, pp. 1–22. doi:10.1080/14693062.2014.965125.

Dechezleprêtre A.; Colmer J.; Gennaioli C.; Glachant M. & Schröder A. (2014). Assessing the Additionality of the Clean Development Mechanism: Quasi-Experimental Evidence from India.

Gillenwater, M. (2012). What is Additionality? Part 1: A long standing problem. Available at http://ghginstitute.org/wp-content/uploads/2015/04/AdditionalityPaper_Part-1ver3FINAL.pdf.

ICAO (2010). Resolutions Adopted by the Assembly, A37-19 Consolidated statement of continuing ICAO policies and practices related to environmental protection – Climate change (November 2010). Available at http://www.icao.int/Meetings/AMC/Assembly37/Documents/ProvisionalEdition/a37_res_prov_en.pdf, last accessed on 26 Sep 2015.

IGES (2015). CDM project database. Available at http://pub.iges.or.jp/modules/envirolib/upload/968/attach/iges_cdm_db_EN.zip.

Kollmuss, A.; Lazarus, M. & Schneider, L. (2014). Single-year mitigation targets: Uncharted territory for emissions trading and unit transfers (Working Paper No. 2014-01). Available at http://www.sei-international.org/mediamanager/documents/Publications/Climate/SEI-WP-2014-01-Single-year-pledges.pdf.

Lee, D. S.; Lim, L. L. & Owen, B. (2013). Bridging the aviation CO2 emissions gap: why emissions trading is needed. Available at http://www.cate.mmu.ac.uk/wp-content/uploads/Bridging_the_aviation_emissions_gap_010313.pdf.

Purdon, M. (2014). Ex-post Evaluation of the Additionality of a Clean Development Mechanism Cogeneration Project in Uganda: The significance of changes in project financing and background economic conditions. Available at http://www.lse.ac.uk/GranthamInstitute/publications/WorkingPapers/Papers/150-59/WP152-Ex-post-evaluation-of-additionality-of-clean-development-cogeneration-project-Uganda.pdf.

Schneider L. (2009). Assessing the additionality of CDM projects: practical experiences and lessons learned. Climate Policy, 9(3), pp. 242–254. doi:10.3763/cpol.2008.0533.

Spalding-Fecher, R.; Achanta, A. N.; Erickson, P.; Haites, E.; Lazarus, M.; Pahuja, N.; Pandey, N.; Seres, S. & Tewari, R. (2012). Assessing the impact of the Clean Development Mechanism. Report commissioned by the High Level Panel on the CDM Policy Dialogue. Bonn. Available at http://www.cdmpolicydialogue.org/research/1030_impact.pdf.

UNEP DTU (2015). CDM Pipeline overview. Available at http://www.cdmpipeline.org/publications/CDMPipeline.xlsm.

6. Annex

Table 2: Exclusion and inclusion of CDM projects by scale, type and sub-type

Scale, Type, Subtype: excluded [Mt]	2021 -2035	2017 -2035
LARGE, Afforestation, Afforestation	5.98	7.62
LARGE, Biomass energy, Agricultural residues: other kinds	138.86	192.71
LARGE, Biomass energy, Agricultural residues: poultry litter	2.73	3.65
LARGE, Biomass energy, Agricultural residues: rice husk	18.13	27.65
LARGE, Biomass energy, Bagasse power	9.58	17.11
LARGE, Biomass energy, Biomass briquettes or pellets	0.44	0.87
LARGE, Biomass energy, Black liquor	3.27	4.70
LARGE, Biomass energy, Forest residues: other	17.75	24.43
LARGE, Biomass energy, Forest residues: sawmill waste	2.85	4.69
LARGE, Biomass energy, Gasification of biomass	0.21	0.37
LARGE, Biomass energy, Industrial waste	3.21	4.26
LARGE, Biomass energy, Palm oil solid waste	5.80	8.95
LARGE, Biomass energy, Switch from fossil fuel to piped bioga	0.25	0.79
LARGE, EE supply side, Higher efficiency coal power	9.46	28.09
LARGE, EE supply side, Higher efficiency oil power	0.55	2.82
LARGE, EE supply side, Higher efficiency steam boiler	0.08	0.17
LARGE, Fossil fuel switch, Coal to natural gas	2.09	3.12
LARGE, Fossil fuel switch, New natural gas plant	112.26	193.78
LARGE, Fossil fuel switch, New natural gas plant using LNG	82.99	131.46
LARGE, Fossil fuel switch, Oil to natural gas	1.84	4.65
LARGE, HFCs, HFC23	538.99	849.74
LARGE, Hydro, Existing dam	62.99	91.15
LARGE, Hydro, New dam	877.63	1,190.33
LARGE, Hydro, Run of river	1,207.05	1,690.79
LARGE, N2O, Adipic acid	187.81	295.01
LARGE, Reforestation, Afforestation	0.13	0.16
LARGE, Reforestation, Agroforestry	0.79	1.00
LARGE, Reforestation, Reforestation	23.58	30.76
LARGE, Wind, Wind	1,928.81	2,652.69
SMALL, Afforestation, Afforestation	0.25	0.32
SMALL, Afforestation, Mangroves	0.03	0.04
SMALL, Biomass energy, Agricultural residues: mustard crop	2.12	3.17
SMALL, Biomass energy, Agricultural residues: other kinds	17.39	28.33
SMALL, Biomass energy, Agricultural residues: poultry litter	1.09	1.66
SMALL, Biomass energy, Agricultural residues: rice husk	8.66	16.24
SMALL, Biomass energy, Bagasse power	1.30	3.32
SMALL, Biomass energy, Biodiesel from waste oil	0.00	0.13
SMALL, Biomass energy, Biomass briquettes or pellets	0.76	2.08
SMALL, Biomass energy, Black liquor	0.15	0.23
SMALL, Biomass energy, Forest biomass	0.55	1.11
SMALL, Biomass energy, Forest residues: other	3.42	5.75
SMALL, Biomass energy, Forest residues: sawmill waste	7.69	13.17
SMALL, Biomass energy, Gasification of biomass	0.47	0.86
SMALL, Biomass energy, Industrial waste	1.62	2.18
SMALL, Biomass energy, Palm oil solid waste	10.68	16.56
SMALL, Biomass energy, Palm oil waste	0.08	0.31
SMALL, Biomass energy, Switch from fossil fuel to piped bioga	0.05	0.26
SMALL, EE supply side, Higher efficiency coal power	0.11	0.26
SMALL, EE supply side, Higher efficiency steam boiler	0.00	0.00
SMALL, EE supply side, Power plant rehabilitation	0.07	0.11
SMALL, EE supply side, Single cycle to combined cycle	0.05	0.18
SMALL, HFCs, HFC134a	0.00	0.14
SMALL, Reforestation, Agroforestry	0.01	0.02
SMALL, Reforestation, Reforestation	0.90	1.15
Total excluded	**5,303.57**	**7,561.11**
Scale, Type, Subtype: included [Mt]		
LARGE, Cement, Clinker replacement	3.65	7.22
LARGE, CO2 usage, CO2 recycling	0.13	0.36
LARGE, Coal bed/mine methane, CMM & Ventilation Air Metha	2.81	7.64
LARGE, Coal bed/mine methane, Coal Mine Methane	72.49	132.99
LARGE, Coal bed/mine methane, Ventilation Air Methane	14.21	19.37
LARGE, EE households, Appliances	0.41	1.49
LARGE, EE households, Lighting	0.08	0.58
LARGE, EE industry, Cement	0.12	0.36
LARGE, EE industry, Chemicals	0.06	0.34
LARGE, EE industry, Food	1.31	1.90
LARGE, EE industry, Iron & steel	0.09	0.42
LARGE, EE industry, Non-ferrous metals	0.76	2.29
LARGE, EE industry, Paper	0.00	0.01
LARGE, EE industry, Petrochemicals	3.07	4.20
LARGE, EE own generation, Building materials heat	0.36	0.55
LARGE, EE own generation, Carbon black gas	0.93	1.74
LARGE, EE own generation, Cement heat	8.05	27.86
LARGE, EE own generation, Chemicals heat	1.50	4.00
LARGE, EE own generation, Coke oven gas	6.75	29.39
LARGE, EE own generation, Glass heat	0.00	0.05
LARGE, EE own generation, Iron & steel heat	48.13	98.66
LARGE, EE own generation, Non-ferrous metals heat	0.07	0.69
LARGE, EE own generation, Petrochemicals heat	0.52	2.78
LARGE, EE service, HVAC & lighting	0.16	0.21
LARGE, EE supply side, Cogeneration	17.62	28.54
LARGE, EE supply side, Higher efficiency using waste heat	0.28	1.05
LARGE, EE supply side, Single cycle to combined cycle	21.91	45.19
LARGE, Energy distribution, Connection of isolated grid	0.91	1.42
LARGE, Energy distribution, District heating	4.95	31.00
LARGE, Fugitive, Charcoal production	0.28	1.72
LARGE, Fugitive, Natural gas pipelines	15.96	53.56
LARGE, Fugitive, Non-hydrocarbon mining	2.21	3.02
LARGE, Fugitive, Oil and gas processing flaring	1.54	4.12
LARGE, Fugitive, Oil field flaring reduction	29.24	61.31
LARGE, Geothermal, Geothermal electricity	126.31	166.54
LARGE, Geothermal, Geothermal heating	0.15	0.73
LARGE, Hydro, Higher efficiency hydro power	1.03	3.08
LARGE, Landfill gas, Combustion of MSW	15.25	25.72
LARGE, Landfill gas, Gasification of MSW	0.05	0.26
LARGE, Landfill gas, Integrated solid waste management	0.13	0.80
LARGE, Landfill gas, Landfill aeration	0.12	0.16

Scale, Type, Subtype: included [Mt] (continued)	2021 -2035	2017 -2035
LARGE, Landfill gas, Landfill composting	5.24	8.36
LARGE, Landfill gas, Landfill flaring	60.85	91.82
LARGE, Landfill gas, Landfill power	107.05	163.61
LARGE, Landfill gas, Switch from fossil fuel to piped landfill ga	2.33	3.04
LARGE, Methane avoidance, Composting	2.28	3.29
LARGE, Methane avoidance, Manure	3.67	7.34
LARGE, Methane avoidance, Palm oil waste	0.23	0.30
LARGE, Methane avoidance, Waste water	11.98	20.88
LARGE, Mixed renewables, Solar & wind	3.98	5.23
LARGE, N2O, Caprolactam	1.53	4.71
LARGE, N2O, Nitric acid	179.07	271.07
LARGE, PFCs and SF6, PFCs	0.00	1.11
LARGE, PFCs and SF6, SF6	4.35	17.08
LARGE, Solar, Solar PV	77.10	104.69
LARGE, Solar, Solar thermal power	8.21	13.73
LARGE, Tidal, Tidal	3.08	4.20
LARGE, Transport, Bus Rapid Transit	6.88	9.58
LARGE, Transport, Mode shift: road to rail	3.56	5.30
LARGE, Wind, Offshore Wind	1.91	2.48
SMALL, Agriculture, Irrigation	0.01	0.03
SMALL, CO2 usage, CO2 recycling	0.00	0.01
SMALL, Coal bed/mine methane, Ventilation Air Methane	13.51	17.66
SMALL, EE households, Lighting	0.72	2.57
SMALL, EE households, Lighting & Insulation & Solar	0.02	0.04
SMALL, EE households, Stoves	0.86	3.10
SMALL, EE industry, Building materials	0.58	1.92
SMALL, EE industry, Cement	0.01	0.03
SMALL, EE industry, Chemicals	0.10	0.45
SMALL, EE industry, Electronics	0.03	0.09
SMALL, EE industry, Food	0.00	0.01
SMALL, EE industry, Glass	0.06	0.08
SMALL, EE industry, Iron & steel	0.00	0.12
SMALL, EE industry, Machinery	0.07	0.10
SMALL, EE industry, Mining	0.05	0.14
SMALL, EE industry, Non-ferrous metals	0.01	0.04
SMALL, EE industry, Paper	0.86	1.67
SMALL, EE industry, Petrochemicals	0.60	0.93
SMALL, EE industry, Recycling	0.07	0.20
SMALL, EE industry, Textiles	0.00	0.04
SMALL, EE own generation, Carbon black gas	0.00	0.12
SMALL, EE own generation, Cement heat	1.60	4.69
SMALL, EE own generation, Chemicals heat	0.16	0.52
SMALL, EE own generation, Glass heat	0.11	0.35
SMALL, EE own generation, Iron & steel heat	0.08	0.20
SMALL, EE own generation, Non-ferrous metals heat	0.01	0.12
SMALL, EE own generation, Petrochemicals heat	0.01	0.20
SMALL, EE service, Air conditioning	0.03	0.08
SMALL, EE service, EE commercial buildings	0.05	0.08
SMALL, EE service, EE new buildings	0.03	0.04
SMALL, EE service, EE public buildings	0.00	0.01
SMALL, EE service, EE Public Stoves	1.60	2.06
SMALL, EE service, HVAC & lighting	0.17	0.28
SMALL, EE service, Street lighting	0.03	0.11
SMALL, EE service, Water pumping	0.01	0.02
SMALL, EE supply side, Cogeneration	0.66	0.92
SMALL, Energy distribution, Connection of isolated grid	0.22	0.28
SMALL, Energy distribution, Efficient electricity distribution	0.10	0.29
SMALL, Energy distribution, Replacement of district heating bo	0.00	0.00
SMALL, Fossil fuel switch, Coal to natural gas	0.52	0.74
SMALL, Fossil fuel switch, New natural gas plant	0.08	0.30
SMALL, Fossil fuel switch, Oil to natural gas	0.34	1.72
SMALL, Fugitive, Charcoal production	0.00	0.01
SMALL, Geothermal, Geothermal heating	0.01	0.02
SMALL, Hydro, Existing dam	6.30	9.20
SMALL, Hydro, Higher efficiency hydro power	0.04	0.05
SMALL, Hydro, New dam	30.13	42.14
SMALL, Hydro, Run of river	179.17	251.59
SMALL, Landfill gas, Biogas from MSW	0.03	0.09
SMALL, Landfill gas, Integrated solid waste management	0.03	0.06
SMALL, Landfill gas, Landfill composting	0.97	1.54
SMALL, Landfill gas, Landfill flaring	1.18	2.03
SMALL, Landfill gas, Landfill power	2.44	5.20
SMALL, Landfill gas, Switch from fossil fuel to piped landfill ga	0.00	0.01
SMALL, Methane avoidance, Aerobic treatment of waste water	0.30	0.51
SMALL, Methane avoidance, Composting	2.88	4.79
SMALL, Methane avoidance, Domestic manure	4.84	9.49
SMALL, Methane avoidance, Manure	14.05	22.01
SMALL, Methane avoidance, Palm oil waste	6.17	11.13
SMALL, Methane avoidance, Waste water	30.52	50.65
SMALL, Mixed renewables, Solar & wind	0.14	0.19
SMALL, Mixed renewables, Wind & hydro	0.04	0.06
SMALL, Solar, Solar cooking	1.38	6.40
SMALL, Solar, Solar lamps	0.03	0.40
SMALL, Solar, Solar PV	19.48	27.28
SMALL, Solar, Solar PV water disinfection	0.00	0.02
SMALL, Solar, Solar thermal heat	0.02	0.05
SMALL, Solar, Solar thermal power	0.14	0.18
SMALL, Solar, Solar water heating	1.22	1.85
SMALL, Transport, Biodiesel for transport	0.16	0.22
SMALL, Transport, Cable cars	0.14	0.20
SMALL, Transport, Mode shift: road to rail	0.00	0.06
SMALL, Transport, More efficient vehicles	0.00	0.00
SMALL, Transport, Motorbikes	0.17	0.59
SMALL, Transport, Rail: regenerative braking	0.00	0.03
SMALL, Wind, Wind	25.99	46.77
Total included	**1,238.48**	**2,048.35**
Total	**6,542.05**	**9,609.46**

Source: Own calculations based on UNEP DTU (2015), IGES (2015)