REDD and the effort to limit global warming to 2°C: Implications for including REDD credits in the international carbon market

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This paper and its supporting numerical model are available for download from: www.kea3.com/reddmodelling

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1. Introduction

Reducing emissions from deforestation and degradation (REDD) has moved firmly onto the agenda as the parties to the United Nations Framework Convention on Climate Change (UNFCCC) approach the climate change negotiations at the Conference of the Parties (COP) 15 at Copenhagen in December 2009. REDD is an option that could rapidly and cost-effectively reduce GHG emissions and could also protect biodiversity and benefit local and indigenous peoples. Furthermore, the engagement of the United States and others has heightened interest in, and debate about, the use of emissions offsets to achieve greenhouse gas (GHG) emissions reduction goals.

In this paper we investigate the impact of implementing REDD in the context of a global effort to combat climate change. Specifically, we explore the effects of incorporating REDD in international carbon markets. We expand on previous modelling efforts by simulating carbon market interactions under expanded Annex I commitments which are aligned with the goal of avoiding a greater than 2.0-2.4°C rise in global temperatures.

Both policy makers and the general reader may find the implications for compliance costs, Annex I abatement and non-REDD offsets of particular interest. Section 1 introduces the context of our study. Section 2 follows with a description of other relevant modelling efforts and our chosen methodology. Section 3 presents high-level results while Section 4 opens discussion on some policy implications of our numerical findings. Section 5 concludes. The appendix contains detailed numerical results.

Context

The human, economic, and environmental costs of even a 2°C rise in mean global temperatures have been assessed as substantial. The Stern review estimates the economic costs of climate change could exceed 20% of Global GDP (Stern 2006, 2008).

The presence of carbon dioxide (CO_2) and other GHGs in the Earth's atmosphere serve to regulate the Earth's energy balance. Increases in the levels of CO_2 and other GHGs will increase the amount of solar radiation which will remain trapped in the Earth's energy system and lead to increased global temperatures.

Human activities are causing the level of GHGs to rise. Fossil fuel combustion contributes approximately 28 Gt CO_2/yr and land-use change contributes another 5.5 Gt CO_2/yr. The increased flux of CO_2 into the atmosphere is partially offset by increased absorption of carbon by the oceans (8.1 Gt CO_2/yr) and other ecosystems (10.3 Gt CO_2/yr), leaving an annual increase of approximately 15 Gt CO_2/yr (Canadell *et al*., 2007).

Land-use change, therefore, figures prominently in this equation. Deforestation is by far the single largest source of land-use change emissions. Lord Stern attributed deforestation with emissions in excess of 8 GtCO_2/yr in 2000 (Stern 2006). These emissions are somewhat offset by absorption through revegetation of cleared lands and reforestation.

Deforestation emissions arise in a number of ways. The largest source is the carbon dioxide which enters the atmosphere when the carbon stored in trees (and other forms of vegetation) is released as a result of burning or as unburned organic matter decays over time. Deforestation also disrupts soil, particularly in peat forests, causing it to release a proportion of its carbon stores into the atmosphere.

The role of REDD

According to the Intergovernmental Panel on Climate Change (IPCC), in order to have a medium likelihood of limiting global temperature rise to 2.0-2.4°C, developed nations will need to reduce their emissions by between 25% and 40% from their 1990 levels by 2020 and to between 80% and 95% by 2050 (Gupta *et al.*, 2007). The IPCC also suggests that in addition to developed country cuts, developing countries will also need to realise significant reductions: a 15%-30% reduction versus baseline in 2020 (den Elzen and Höehne, 2008).

With deforestation emissions representing up to 20% of anthropogenic emissions (Schlamadinger *et al*., 2007), REDD has been heralded as being instrumental to developing the scale of reductions necessary to limit the increase in global temperatures to 2°C. At the same time, proponents note investments in protecting tropical forests could richly reward biodiversity protection and improve livelihoods.

What remains clear is that it is critical for the overall effort to mitigate the harmful effects of climate change that significant reductions in deforestation are required by the year 2020 to provide a reasonable chance of global temperature remaining below 2°C (Norway, 2008).

REDD design issues

Most REDD proposals identify global funds or emissions trading markets (or both) as preferred sources of funding.[1]

Market advocates cite the advantages of economic efficiency and the ability to mobilise the large amounts of capital. Advocates of funds emphasise the potential impacts of integration with emissions markets such as volatility, a reduced carbon price signal, and the substitution of low-quality units for higher quality ones.

Some proponents propose intermediate options that seek to avoid the problems of REDD integration with the broader carbon market but that could provide greater capital mobilisation than through a traditional fund. For example, the dual markets approach from the Center for Clean Air Policy attempts to leverage the power of market driven investment allocation while avoiding complications of direct integration into global compliance markets (Ogonowski et. al., 2007). Similarly, the hybrid Tropical Deforestation Emission Reduction Mechanism (TDERM) proposal by Greenpeace specifies the creation of a special unit, the Tropical Deforestation Emission Reduction Unit (TDERU), which would represent both emissions abatement and other ecosystem services. Developed nations would take on requirements to purchase TDERUs as part of their overall emission reduction commitments (Hare and Macey 2007; Thies and Czebiniak, 2008).

Measurement accuracy, non-permanence issues, and leakage are some of the numerous complications that must be addressed in designing a REDD mechanism. Measurement difficulties include the difficulty of establishing the precise area and carbon content of forests and accounting for inter-annual variation of deforestation rates. As most proposals provide for an incentive payment for reductions in the rates of deforestation, it is important to be able to accurately identify what the deforestation rate would have been to avoid the generation of "hot air" (a situation where compensation will be paid for

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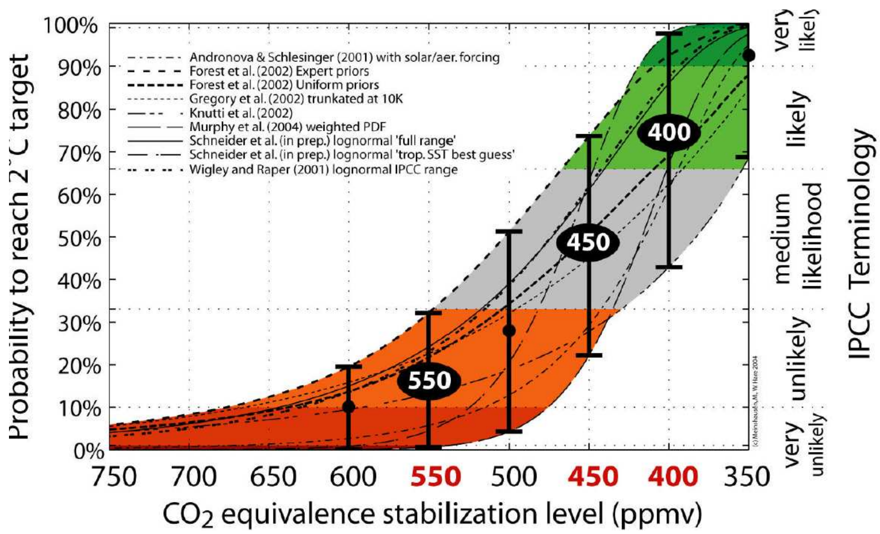
[1] Overviews of existing REDD proposals include Loisel (2008), Dixon and Livengood (2008), Karousakis (2007), and Global Canopy Foundation (2009).

Box 1: Notes on the 2˚C target assumption

For the purpose of this report we have focused on emissions reductions consistent with the goal of maintaining a medium likelihood of keeping the global average temperature rise limited to 2˚C. How do we assess what reductions are necessary to meet this goal? (See Box 2 in the references section for a selection of relevant sources.)

Hare and Meinshausen (2006) aggregated the results from 11 global climate models and developed a probabilistic representation (Figure 1) which shows that a 450 ppm CO_2-eq stabilisation level is required for a medium likelihood of reaching the 2˚C goal.

Figure 1 Probability of reaching a 2° C target by CO_2 stabilization level



The IPCC, in Box 13.7 of the IPCC 4th Assessment Working Group III report (Figure 2)(IPCC 2007), delineated its estimates of what emission reductions would be required to limit the atmospheric concentration of GHGs to 450 ppm CO2-eq.

Figure 2 IPCC Box 13.7

Box 13.7: The range of the difference between emissions in 1990 and emission allowances in 2020/2050 for various GHG concentration levels for Annex I and non-Annex I countries[a]

Scenario category	Region	2020	2050
A-450 ppm CO_2-eq[b]	Annex I	-25% to -40%	-80% to -95%
	Non-Annex I	Substantial deviation from baseline in Latin America, Middle East, East Asia and Centrally-Planned Asia	Substantial deviation from baseline in all regions
B-550 ppm CO_2-eq	Annex I	-10% to -30%	-40% to -90%
	Non-Annex I	Deviation from baseline in Latin America and Middle East, East Asia	Deviation from baseline in most regions, especially in Latin America and Middle East
C-650 ppm CO_2-eq	Annex I	0% to -25%	-30% to -80%
	Non-Annex I	Baseline	Deviation from baseline in Latin America and Middle East, East Asia

Notes:

[a] The aggregate range is based on multiple approaches to apportion emissions between regions (contraction and convergence, multistage, Triptych and intensity targets, among others). Each approach makes different assumptions about the pathway, specific national efforts and other variables. Additional extreme cases – in which Annex I undertakes all reductions, or non-Annex I undertakes all reductions – are not included. The ranges presented here do not imply political feasibility, nor do the results reflect cost variances.

[b] Only the studies aiming at stabilization at 450 ppm CO2-eq assume a (temporary) overshoot of about 50 ppm (See Den Elzen and Meinshausen, 2006).

reductions that would have occurred anyway). Leakage would arise if deforestation is reduced in one country or region, but consequently increases in another area due to the continued presence of demand for timber or arable land or a shifting of extractive capital.

If REDD is to be included in an international agreement, it is critical to ensure the environmental integrity of any REDD activities, while providing incentives for investment in a viable source of emissions reductions. Failure to achieve both of these objectives carries a risk of falling short of our goal of keeping global temperature rise as low as possible.

Toward some clarity

This study evaluates the wholesale integration of REDD into global carbon markets. Partial integration, parallel markets, or dual-market scenarios are not addressed in this study.

We focus on activity levels inline with the overall goal to keep the global temperature increase to below 2˚C. To maintain relevance to this goal, we simulate a range of emissions reduction commitments consistent with the 2˚C target. We also analyse commitment levels consistent with recently stated national emissions reduction targets.

We explore the dynamics of market integration in the year 2020. The study provides information on relative investment levels, price impacts, financial transfers, and net economic benefit for the Annex I region, Clean Development Mechanism (CDM) regions, and REDD regions. Although serious qualitative questions have been raised about potential REDD credits, as well as for the CDM, the quality of all reductions is assumed to be equivalent for the purposes of simulating market interactions.

2. Modelling of REDD carbon market interactions

2.1 Previous work

Anger and Sathaye (2008) investigated the detailed implications of integrating REDD into international carbon markets utilising a multi-region, partial equilibrium model. They predicted international carbon prices could roughly halve in 2020 if REDD credits were provided full access to carbon markets.

Anger *et al.* (2009) expanded on the assumptions of the Anger and Sathaye work. Policy scenarios with supply and demand restrictions on REDD credit trading were added. The impact of increased commitment levels and sensitivity to REDD credit supply were also explored. The study found that if there were no restrictions on access of REDD credits to emissions markets, Annex I emissions would need to be capped at approximately 23% below 1990 levels (60% lower than business-as-usual) in order to avoid a reduction in the international carbon price.

The Eliasch review, released at the end of 2008, also modelled the impacts of incorporating REDD units in international carbon markets. The review integrated updated estimates of deforestation opportunity costs from GCOMAP (Generalized Comprehensive Mitigation Assessment Process, Sathaye *et al.*, 2008) into the United Kingdom Office of Climate Change Global Carbon Finance Model (GLOCAF) model. The review concluded that, if supplementarity limits are utilised, introducing REDD has a minimal impact on the overall price of carbon. The report concludes that supplementarity requirements are sufficient to prevent adverse carbon price impacts due to the existence of a large supply of similar cost mitigation within Annex I economies (Eliasch, 2008).

The Environmental Defense Fund (EDF) utilised a spreadsheet model to investigate the impact of REDD unit imports on compliance markets in the European Union and the United States. Under the EDF's model, the use of REDD credits reduces the permit price by approximately 13%, compared with Anger *et al.*'s estimate of a 45% decrease in the international permit price. The unlimited banking of REDD credits is a key policy assumption of the EDF model. Banking is incorporated by equalising the real price of carbon over time using a 5% discount rate (Cabezas and Keohane, 2008).

Estimates for the quantity of emissions reductions that can be delivered from REDD vary, as do the estimates of the cost of reductions. Comparison amongst the modelling results can be problematic, however, as assumptions are often inconsistent. For example, Sathaye *et al.* (2008) calculate the total baseline deforestation for 2020 as 4.5 $GtCO_2$-eq per year. This figure is somewhat less than the 5.8 Gt CO_2-eq emitted from deforestation activities since 1990 according to the IPCC (2007). The EDF study adopted baseline deforestation data from the Energy Modeling Forum 21 (2003) which identifies baseline emissions of between 1.5 and 2.8 Gt CO_2-eq due to tropical deforestation in 2020.

2.2 Modelling approach

Following from Anger & Sathaye (2008) and Anger *et al.* (2009), we utilise a numerical partial equilibrium model of the global carbon market in the year 2020 to quantify the carbon market impacts of integrating reduced deforestation credits. The model enforces a balance between the supply and demand for emissions reductions in an international, post-2012 compliance market.

The demand for emissions reductions in the model is constant and equivalent to the net global emissions reduction commitment for the post-2012 period.

The model employs marginal abatement cost functions based on energy-system data. Marginal abatement cost functions for REDD are integrated into the model by treating tropical rainforest areas as explicit model regions. Within this model framework, developing countries may export emissions reduction credits from reducing deforestation to Annex I regions via the global carbon market.

In order to maintain consistency with previous work, energy intensive and non-energy intensive sectors for Annex I and CDM regions are incorporated into the model independently.

A partial equilibrium model has been selected based on the ability of such models to represent the specific institutional characteristics of the future carbon market and explicitly incorporate marginal abatement cost functions. This approach facilitates an explicit analysis of carbon price development, regional emission reductions and carbon credit flows emerging from alternative climate policy regimes.

The modelling thus represents a transparent approach that allows simulation results to be easily interpreted by policy makers. A file containing the model code which can be used to replicate the results of this paper is available for download from www.kea3.com/reddmodelling or www.greenpeace.org/forestsforclimate. The file is coded in the General Algebraic Modelling System (GAMS) format.[2]

2.3 Scenarios

Commitments

We focus on quantifying REDD's impact on efforts to limit the increase in average global temperature to a 2˚C range. The base case assumes commitments are equivalent to publicly stated targets as of December 2008. In percentage terms, our base case represents a 12.1% global reduction versus business-as-usual emissions in 2020, but a 34% increase from 1990 levels.

The other commitment levels modelled are within the range of a 25% to 40% reduction in Annex I emissions (compared to 1990 levels) recommended by the IPCC as necessary to avoid a greater than 2.0-2.4˚C rise in global temperatures (see Box 1). Aggregate Annex I reductions of 25%, 30% and 40% versus 1990 levels are modelled.[3]

Policy variables

The carbon market is first simulated without REDD credits to establish a reference case. Integration of REDD units without restriction is then studied. Demand restrictions – or supplementarity requirements – are simulated in the model. Twenty percent and 50% supplementarity requirements[4] were chosen for analysis.

Our simulation assumes that the CDM will continue, in its current form, into the post-2012 period. Furthermore, it is assumed that there are no restrictions on the integration of CDM units into the global carbon market.

It is also assumed that REDD credits are either directly fungible in the international compliance market or they are widely integrated into regional

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[2] See http://chentserver.uwaterloo.ca/courses/Che720a/michelle/integer%20programming/GAMS/www_us/ Default.htm for more information on GAMS.

[3] For the purposes of this paper, a "25% reduction target" will refer to a 25% reduction in Annex I emissions versus 1990 levels. The same convention is used for 30% and 40% reduction targets.

[4] For the purposes of this study, a 20% supplementarity requirement refers to limiting Annex I import of REDD credits to 20% of Annex I mitigation requirements with respect to the baseline. By contrast, in the Second Phase of the EU ETS, imports of Joint Implementation (JI) and CDM credits were limited to 13% of a region/sector's emissions cap. For the Third Phase, a proposal has been made to allow up to 50% of any increases in commitments to be met by JI or CDM credits. See European Commission (2008).

emissions trading schemes and it is therefore possible to abstract to global trading.

Sensitivity

The supply and cost of REDD credits can and is highly uncertain. Natural effects (such as drought, fire or pests), agricultural prices, and land-use policy can greatly affect the rate of deforestation and consequently the supply of REDD credits to the international market.

The design of a REDD mechanism may also influence the supply of REDD credits to the market. For example, if a REDD mechanism's baselines were set higher than our modelled baseline, the supply of REDD credits would expand. Conversely, if a REDD mechanism led to discounting of REDD credits, or if it involved strict quality measures which limited participation, the resulting REDD supply could be much less than we model. Due to these factors which contribute to uncertainty of supply, we tested sensitivity around REDD supply.

A summary of the modelled scenarios is shown in Table 1.

Table 1 Modeled scenarios

Scenario	REDD access	Commitment levels (Annex I vs. 1990)
BASE CASE	No access	Current Commitments
BASE 25PCT		25% reduction
BASE 30PCT		30% reduction
BASE 40PCT		40% reduction
REDD_SUP20_CUR	20% Supplementarity Limit	Current Commitments
REDD_SUP20_25		25% reduction
REDD_SUP20_40		40% reduction
REDD_SUP50_CUR	50% Supplementarity Limit	Current Commitments
REDD_SUP50_25		30% reduction
REDD_SUP50_40		40% reduction
REDD_CUR	Unlimited	Current Commitments
REDD_25PCT		25% reduction
REDD_30PCT		30% reduction
REDD_40PCT		40% reduction

2.4 Key assumptions

The regional grouping applied to the model framework is shown in Table 2. While the model calculates abatement for each of the regions separately, we have aggregated the demand for emissions reductions credits from Annex I countries. This allows the total Annex I commitment level to be adjusted without explicitly determining a burden sharing arrangement for each scenario.

Table 2 Regional grouping

International emissions trading (Annex I) regions	CDM regions	Tropical rainforest regions
EU-27 Canada Japan Former Soviet Union Pacific OECD United States	Brazil China India Mexico South Korea	Africa South-East Asia Central America South America

Historical carbon emissions and baseline data used in the simulation are shown in Table 3 in Appendix A. The baseline projects global emissions to increase 52.4% between 1990 and 2020.

The MAC functions employed in the model for the Annex I and CDM regions are taken directly from Anger *et al.* (2009). The functions take the form of third-degree polynomials based on results from simulations by the energy system model POLES (Criqui *et al*, 1999). POLES explicitly models energy technology options for emissions abatement in various world regions and sectors. In the POLES simulations a sequence of carbon taxes was imposed on the respective regions to identify sectoral emissions abatement. Following Böhringer *et al.* (2005), the coefficients for MAC functions in 2020 are estimated by an ordinary least squares (OLS) regression of marginal abatement costs and associated emissions abatement. Table 4 in Appendix A shows the MAC coefficients by region and sector in 2020.

MAC functions for reducing deforestation are generated by applying a similar methodology as above to results obtained from the GCOMAP model. Net carbon stock changes are established by applying a sequence of carbon prices (here: 5 to 100 US$ per ton of carbon) to the rainforest regions within the GCOMAP model. Table 5 (in Appendix A) illustrates the MAC coefficients for avoided deforestation for the four tropical regions in 2020. Departing from Anger *et al.* (2009), we have utilised updated GCOMAP data from Sathaye *et al.* (2008) which was incorporated in modelling for the Eliasch review. As mentioned above in Section 2.1, Sathaye *et al*. estimated a baseline emissions level of 4.5 GtCO_2/yr from deforestation in 2020.

3. Modelling results and assessment

3.1 Results and assessment for current commitments

The carbon market simulation of our base case, which allows the import of CDM offset credits to meet publicly stated targets, yields a carbon price of 16.0 €/tCO_2.[5] Introducing REDD credits without restriction reduces the international price of carbon 61% to 6.2 €/tCO_2. A previous study obtained carbon prices of 15.7 €/tCO_2 and 8.6 €/tCO_2 respectively for these scenarios (Anger *et al.* 2008).

Abatement

Figure 3 illustrates the relative scale of share of abatement between Annex I and offset sources across the scenarios for current commitments. It shows a 57% reduction in Annex I domestic abatement when REDD is introduced into the carbon market without restriction under the REDD_CUR scenario. As the total emissions reduction is fixed for these scenarios, introduction of REDD imports displaces domestic Annex I emission reductions and exports from the CDM regions. Forty-six percent of the REDD volume substitutes Annex I domestic abatement and the remaining 54% substitutes CDM credits.

Application of supplementarity restrictions increases domestic abatement by restricting the import of REDD credits. Demand is limited, yet each rainforest region is unrestricted in bringing REDD credits to market. This leads to a price separation between the clearing price for REDD credits (2.1 €/tCO_2) and the international carbon price (12.6 €/tCO_2) when 20% supplementarity is applied to REDD trading under current targets.

While the supplementarity approach would increase both the international carbon price and domestic abatement, a 20% supplementarity limit would result in 33% of the deforestation reductions achieved under the unrestricted scenario.

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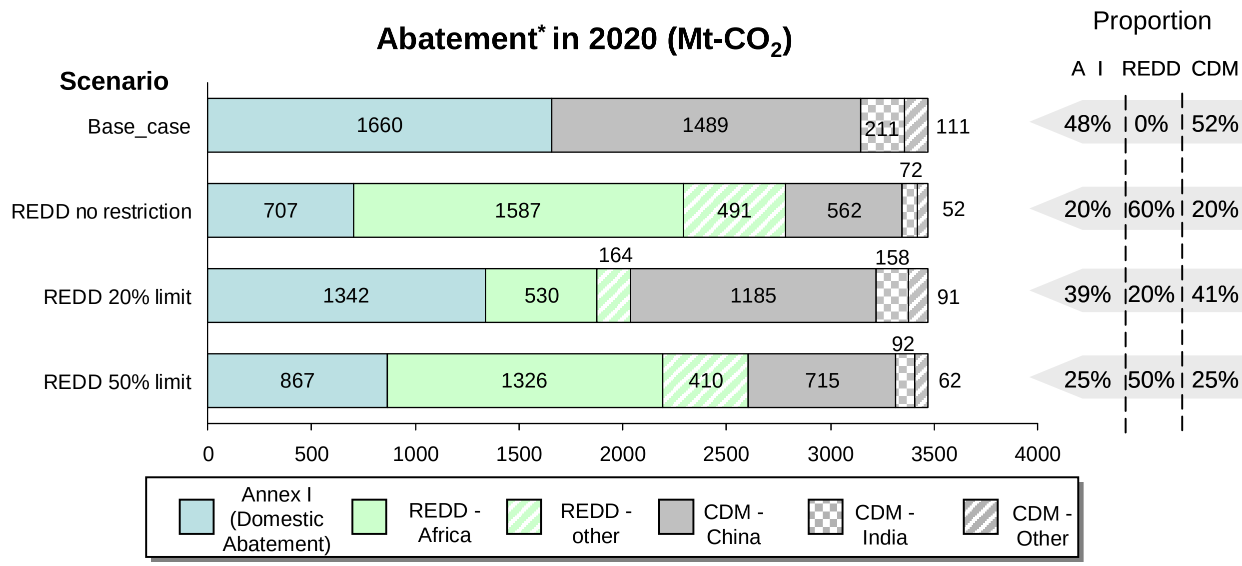
[5] Carbon prices in this report should be considered representative and useful for comparison between scenarios rather than as a prediction for the actual price of carbon in the year 2020. Carbon prices are in 2005 euros.

Assuming an average biomass value of 250 t-CO_2/ha[6], this equates to a difference of 5.5 million hectares of deforestation annually.

Figure 3 CO2 Emission abatement in 2020 by source by scenario – stated targets



(*) Abatement shown versus baseline (business-as-usual)

Environmental impact

For the purposes of our simulation, we assume that the rules for REDD mechanisms effectively address environmental integrity issues with REDD credits. Provided the emissions reductions associated with a REDD credit are actually equivalent to those associated with domestic Annex I reductions, the net flux of CO_2 into the atmosphere in 2020 would be equivalent under each scenario. If REDD credits were less representative of actual emissions reductions than comparable Annex I or CDM units, however, then more CO_2 would be emitted to the atmosphere under any of the REDD scenarios than in the case without REDD integration.

Compliance costs and financial transfers

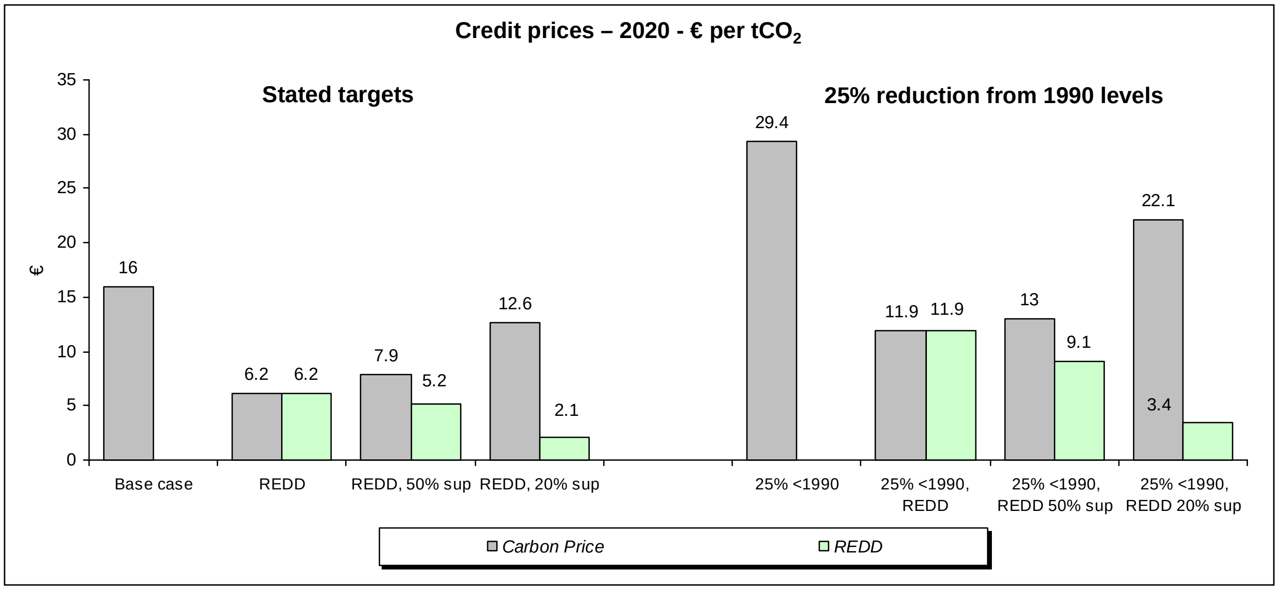
Compliance costs[7] generally decrease for Annex I as the price of carbon decreases. In the case of full REDD fungibility, Annex I compliance costs decrease 54% with the introduction of the additional supply of offsets. While

[6] This value corresponds to the average biomass value for Africa used in the GCOMAP model (Sathaye *et al.* 2008).

[7] Compliance costs are defined as the cost of domestic abatement plus the net import of carbon credits times the price of carbon and the net import of REDD credits times the REDD price.

the simulations show that the scenario with the lowest net global compliance cost is the REDD_CUR scenario, the lowest compliance cost scenario for Annex I is the 50% supplementarity scenario. This is because supplementarity allows Annex I to pay less for low-cost REDD abatement than for abatement from other sources which receive the full international carbon price (see Figure 4).[8]

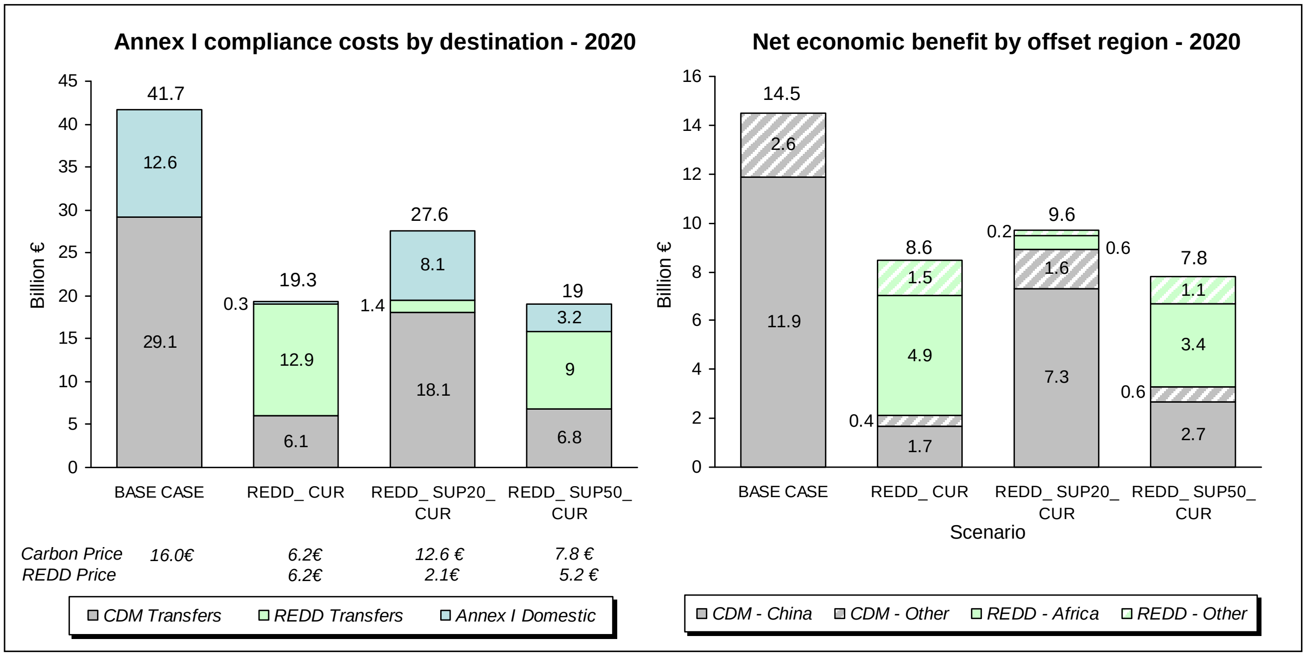
Figure 4 Credit prices – stated targets and 25% reduction target



The economic benefit to CDM countries is significantly affected under full REDD fungibility. Financial transfers to CDM regions decrease 34%. The net economic benefit (the total of the transfers less mitigation costs) declines 86% relative to the scenario without REDD.

8 This case can arise where higher domestic abatement and CDM costs are offset by a quantity of low cost REDD units.

Figure 5 Annex I compliance costs, offset region net economic benefit – stated targets



3.2 Results and assessment for expanded commitment scenarios

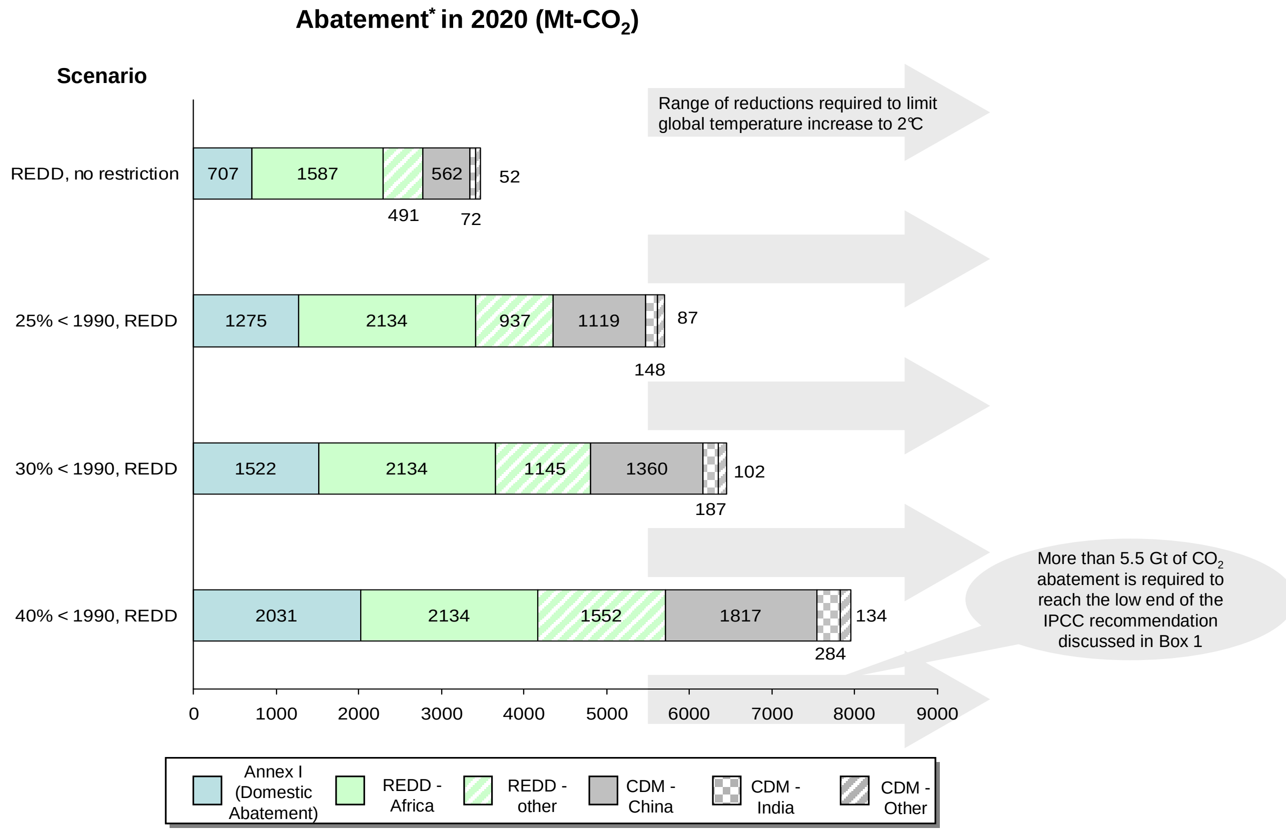
Our numerical simulation of the global compliance carbon market in the year 2020 shows, as expected, increasing carbon price and compliance costs as increasing emissions reductions commitments are adopted. Without integrating REDD, the price of carbon increases from 16.0 €/tCO_2 for currently stated targets to 47.8 €/tCO_2 if Annex I nations collectively cap emissions 40% below 1990 levels.

Introduction of REDD credits to the international carbon market reduces the price of carbon by 59% under the 25% reduction target (from 29.4 € to 11.9 €) and by 57% under a 40% reduction target (from 47.8 € to 20.4 €).

Abatement

Figure 6 below illustrates the relative scale of share of abatement between Annex I and offset sources for each of the emissions reduction levels simulated.

Figure 6 Abatement by source, expanded commitments



(*) Abatement shown versus baseline (business-as-usual)

As with our analysis of currently stated emissions reductions targets in Section 3.1, the introduction of REDD under expanded targets reduces both Annex I domestic abatement and abatement in CDM regions. Under the 25% reduction target, Annex I domestic abatement drops by 53% when REDD credits enter the market with no restrictions, while CDM abatement falls by 55%. With a 30% reduction target the corresponding abatement reductions are 51% and 50% respectively.

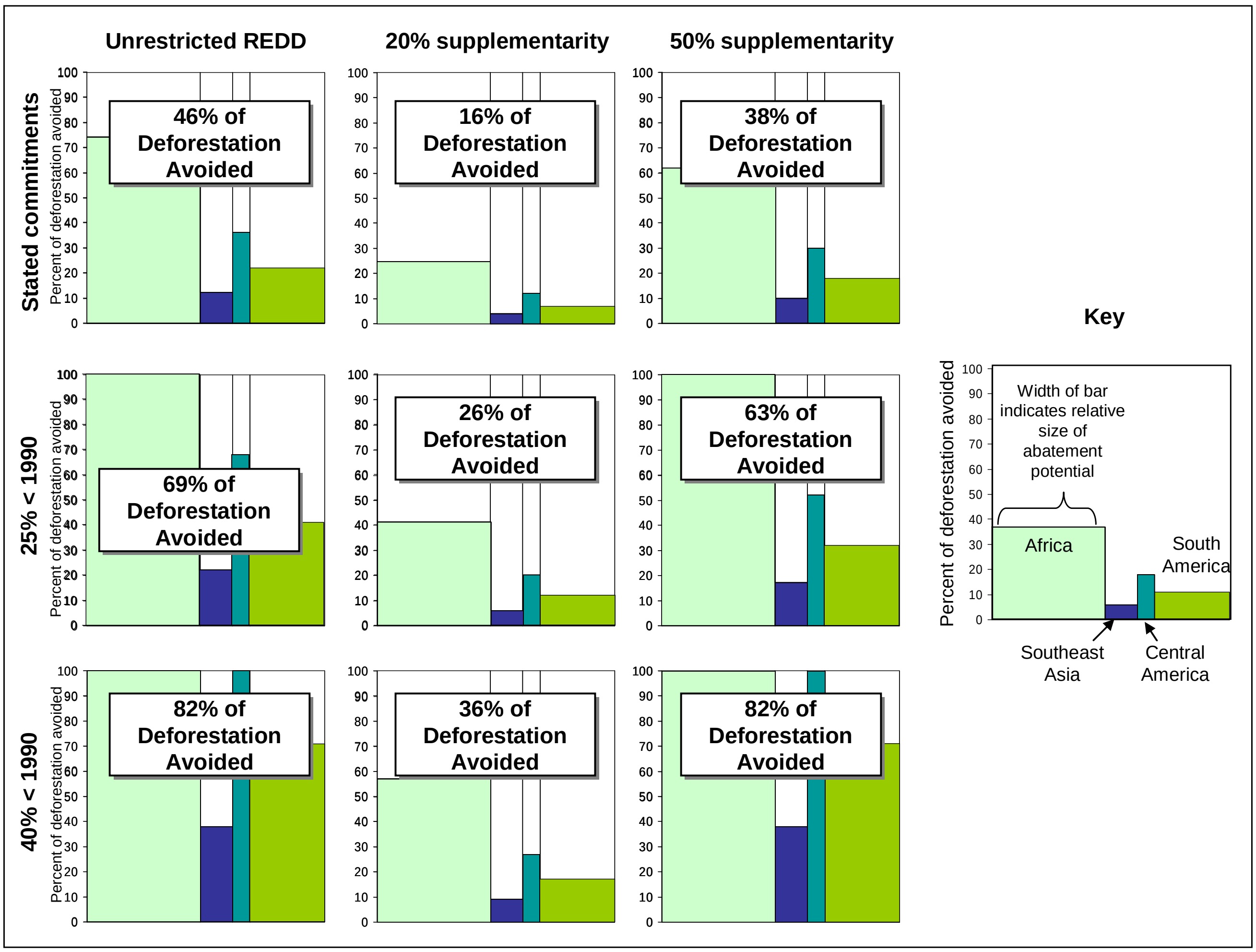
As emissions reductions commitments deepen, both Annex I domestic abatement and CDM abatement regain share as inexpensive REDD options are exhausted and deforestation is virtually halted in Africa and Central America. Under the 40% reduction scenario, both CDM and Annex I domestic abatement are reduced by 46% with the introduction of REDD compared to the no-REDD case.

Environmental impact

In Section 3.1 we discussed the potential environmental impact of introducing REDD into the international carbon market from the perspective of comparative unit quality. Here we discuss the effectiveness of incorporating REDD into the carbon market for reducing or halting deforestation under the various scenarios.

Supplementarity restrictions significantly impact the amount of deforestation which can occur through a market-based mechanism. As seen in Figure 7, our simulations show that nearly 82% of deforestation can be avoided in 2020 if Annex I emissions are capped at 40% of 1990 levels and REDD credits are accepted into the international carbon markets. Limiting the import of REDD units into the market to 20% of Annex I's required reductions from baseline results in only 16% of the baseline deforestation being avoided.

Figure 7 Deforestation avoided by scenario – deforestation avoided in 2020 as a percentage baseline

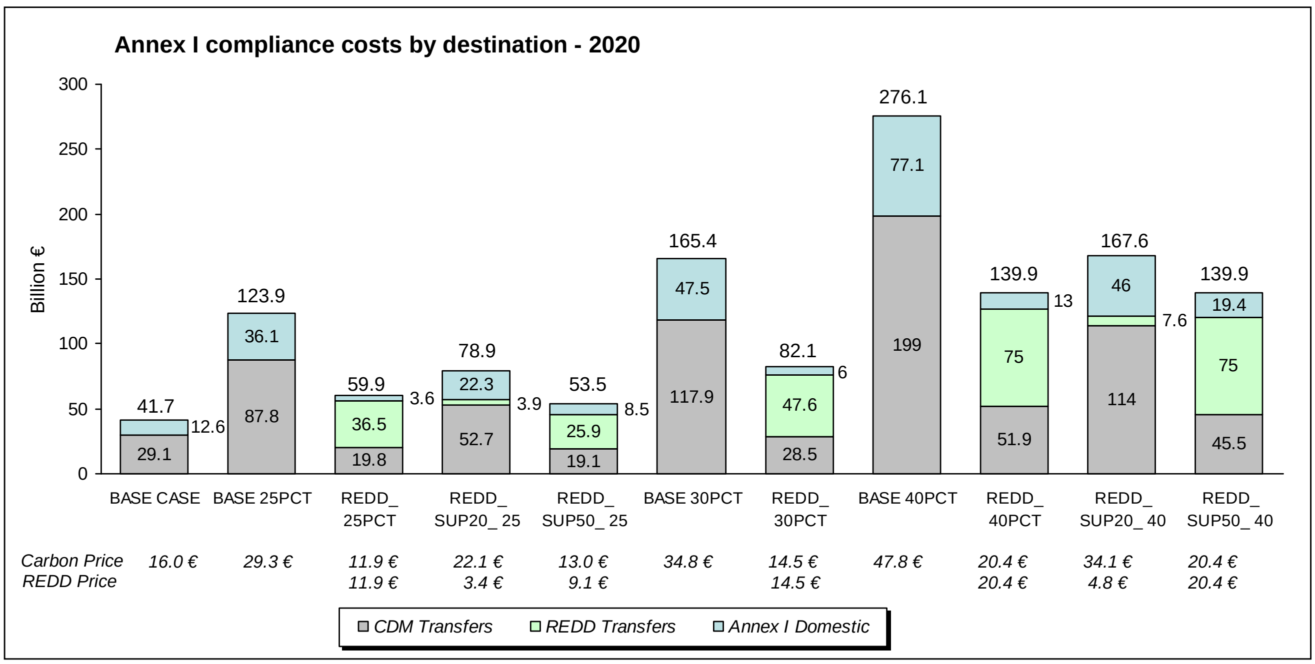


Compliance costs and financial transfers

Expanded commitments by Annex I nations are accompanied by higher compliance costs. This is a result of not only a greater requirement for emission reductions, but a higher marginal cost for each unit. Furthermore, as lower-cost domestic abatement is exhausted, a greater percentage of emissions reductions occur outside Annex I, resulting in significant financial transfers.

As shown in Figure 8, total Annex I compliance costs under the base case without REDD are 41.7 billion € per year. These costs increase more than three-fold to 123.9 billion € with a target of 25% below 1990 levels. At 40% below 1990 levels, compliance costs increase more than six fold to 276 billion € per year.

Figure 8 Annex I compliance costs and related transfers – expanded commitments



3.3 Sensitivity to REDD supply

The variability in the availability of REDD units is a substantial risk for including REDD in the international carbon market. Oversupply could collapse prices (for example, the EU ETS experience) and affect longer term investment in abatement programmes. An unexpected undersupply of REDD units could leave a large pool of demand chasing the few mitigation sources which are able to respond to price signals, resulting in high prices.

We simulated the impact of an oversupply situation and an undersupply situation in order to ascertain if the results were robust to these variations. The undersupply situation was represented in the model by reducing the supply of REDD credits for any given price to 50% of the base amount. The oversupply scenario was simulated by doubling the number of units supplied at each price for each region.

For currently stated targets, unlimited REDD trading and the high REDD credit supply case, our simulations show a 75.7% price decrease from 16.05 €/tCO_2 to 3.9 €/tCO_2. Should half as many REDD credits be delivered at a given price as in our model, the market clearing price with REDD and currently stated targets increases 43% from 6.2 €/tCO_2 to 8.9 €/tCO_2.

The large market share of REDD units, combined with the effective elasticity of demand for REDD credits, leaves the overall market price susceptible to significant price volatility should such large supply variations occur.

For the 40% reduction targets, unlimited REDD trading and the high REDD credit supply case, our simulations show a 70.62% price decrease from 47.76 €/tCO_2 to 14.03 €/tCO_2. (an additional 31% price decrease from 20.4 €/tCO_2 to 14.0 €/tCO_2 compared to our base scenarios). If half as many REDD credits are delivered, the market clearing price with REDD and currently stated targets increased 17% from 20.4 €/tCO_2 to 24.0 €/tCO_2. The relatively small increase in price with the lower REDD supply level is due to the fact that, under our normal REDD supply assumptions and 40% reduction targets, deforestation had halted in Africa and Central America leaving more expensive regions to set the clearing price.

Partial sensitivity results are shown in Table 11 in Appendix B. Detailed sensitivity results are available at www.kea3.com/reddmodelling.

4. Policy Implications

Our simulation assesses a range of commitments consistent with targeting a maximum 2°C rise in global mean temperature. It evaluates the impact of the integration of REDD credits into the international carbon market in the year 2020. As we have shown in Sections 3.1 and 3.2, the anticipated supply of REDD credits will depress global carbon prices around 60% if commitments are not increased or if there are no supplementarity restrictions.

Our simulations explicitly show displacement of Annex I domestic abatement in all scenarios where REDD is included in the market. This displacement occurs because REDD activities can generate credits at a lower cost than some CDM or Annex I domestic abatement activities. This flows through to a lower overall carbon price.

While our model does not explicitly assess feedback effects resulting from the inclusion of REDD in the carbon market, the predicted changes to the price of carbon can allow us to discern at a qualitative level what some of these effects may be.

A lower overall net abatement cost may lead to greater levels of overall consumption relative to the base case (rebound effect) in both the developed world (which benefits from reduced compliance costs) and the offset regions (which benefit from increased financial inflows). The overall net abatement cost reduction will be partially offset by increases in agriculture and timber prices due to restrictions on the supply of arable land and unsustainable timber extraction as a result of REDD activity.

The reduction in global carbon price levels will reduce incentives to invest in low emissions technology and infrastructure. For example, the expectation of a low carbon price could increase the attractiveness of a coal-fired power plant. Once an investment has been made in high emissions infrastructure, capital costs are sunk and users are likely to accept large increases in carbon prices (or lobby against their imposition) before upgrading to cleaner technologies (lock-in effect).

Clean technology is expected to develop faster under a high-carbon price scenario as compared to a low carbon price scenario. For example, the IPCC found that in order to have a medium likelihood of staying within the 2.0-2.4°C range (stabilisation between 445 and 490ppmv CO2-eq) the price for carbon would need to be in the range of € 80/tCO_2-eq (US$100) (IPCC AR4 WGIII, Chap 3 at 205-206). Staying below 2°C would therefore require an even stronger carbon price signal.

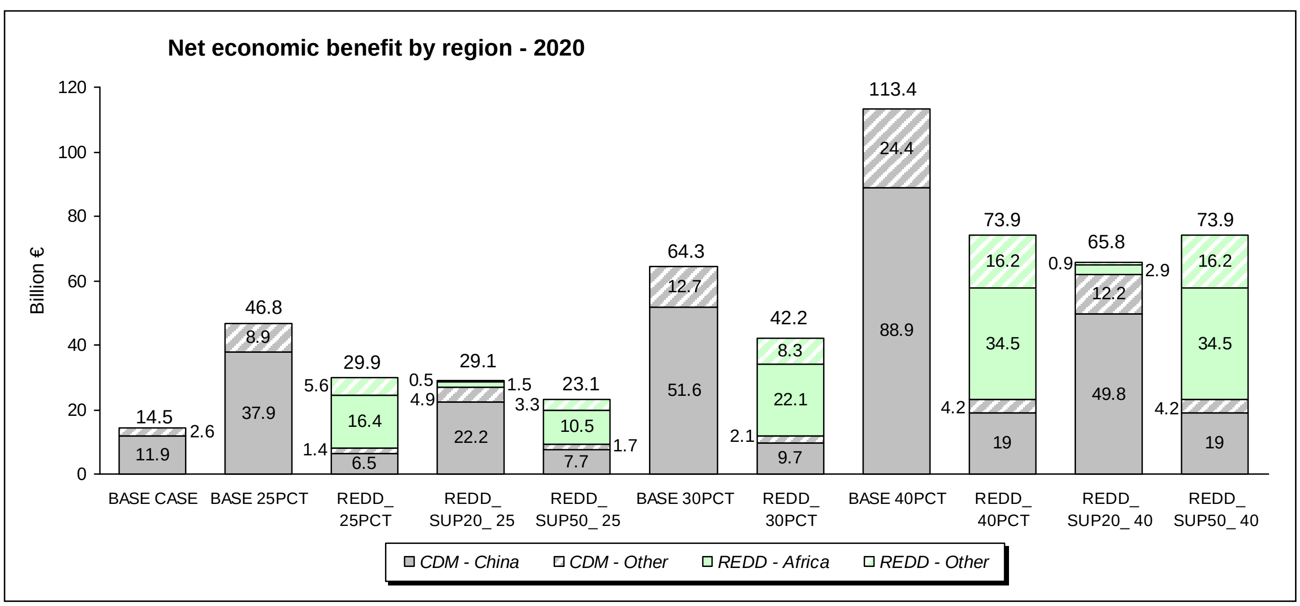
It can be expected that as clean technology evolves in the developed world it will permeate to the developing world, leading to emissions reductions versus the baseline. The speed and magnitude of this transfer will vary by region and technology. The relative expense and difficulty in financing capital investments in the developing world can slow technology transfer (Sathaye and Phadke, 2006). On the other hand, some technologies enable less capital-intensive development pathways and may even be adopted more readily in developing nations.[9] In either case, delayed development of clean technologies will drive development along a higher-carbon path.

Windfall profits

The potential for REDD to generate large emissions reductions at a low cost relative to other mitigation options will make some REDD activities highly profitable if REDD credits are sold on the international carbon market at the international carbon clearing price.

Figure 9 shows the size of the profits for the African rainforest region (solid green) relative to the profits of other offset regions. Our model shows that Africa is the primary beneficiary of REDD because of the extensive low marginal abatement cost opportunities there. While an unrestricted REDD regime would result in large profits earned by REDD nations, limiting the REDD price through supplementarity requirements limits profits but would result in smaller reductions in deforestation.

Figure 9 CDM, REDD economic benefit – expanded commitments



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9 The telecommunications sector is an example of where this might occur. Developing nations moved directly to wireless and fibre optic technologies, sidestepping expensive investments in extensive copper wire networks. At the same time, many developed nations still maintained existing investments their copper networks.

In our simulations, deforestation in Africa is completely halted under the 30% and 40% reduction target scenarios that involve unrestricted REDD imports. Continued increases in the REDD price will add to the economic benefit of the African region without generating additional mitigation. Mechanism designers may seek to limit producer surplus in such situations and re-allocate resources to other areas.

Large international transfers may lead to significant feedback effects. As developing nations acquire wealth, consumption may increase, resulting in an increase in emissions within economies that are not subject to emissions caps.

Interests of purchasers and other suppliers of units

The integration of REDD units into the global carbon market in any form affects the interests of both purchasers and other suppliers of emission units.

With the introduction of REDD into the carbon market, CDM regions face competition for the supply of units and therefore would suffer a reduction in net economic benefit. Depending on the future of the CDM programme, these losses can be sizable. Our simulations suggest China's loss under unlimited REDD fungibility with stated commitments exceeds € 10 billion in 2020.

Addressing environmental concerns with REDD

If REDD mechanisms could be developed that would assure that the REDD credits generated were environmentally equivalent to emissions reductions from other sectors, the most economically efficient outcome would result from unrestricted trading of REDD credits in the global carbon market. At present, such assurances about environmental quality of REDD credits cannot be made, however.

Given the as-of-yet unsolved issues of leakage, permanence, and baseline selection, conservative approaches to integrating REDD credits into the carbon market may be preferable.

5. Conclusion

REDD has the potential to deliver large emissions reductions and to reduce compliance costs. REDD also has the potential to deliver emissions reductions in the short and medium term and thus is fundamental to achieving the dramatic emissions reductions necessary by 2020.

There are several options available to policy makers for incorporating REDD in the overall approach to combating climate change. In this paper we evaluated the impact in 2020 of the integration of REDD units into the international carbon market together with emissions reductions consistent with the IPCC's recommendations for achieving a medium likelihood of limiting global warming to 2°C.

Focusing on the upper end of the IPCC's recommended emissions reductions (-40%), we found that providing REDD unrestricted access to the carbon markets would reduce tropical deforestation by 82% overall and reduce compliance costs by 49%, at the cost of lowering the price of carbon by 57% percent.

In all of our simulated scenarios, the integration of unrestricted REDD credits into the international carbon market displaces other emissions reduction activities such as Annex I domestic abatement. It is also likely to discourage the development of clean technologies through a weaker price signal.

Additionally, our simulations show the unrestricted integration of REDD will halve the production of credits relating to energy and industrial emissions reductions in China, India and other developing countries which could significantly delay the deployment of clean technologies in these regions.

However, it is unclear if, in the absence of the cost-moderating effects of REDD, the ambitious goals proposed by the IPCC will be agreed. Significant financing for REDD will therefore need to be raised in a manner that allows for the maximum overall emission reductions and does not overly reduce or delay necessary investments in clean and renewable technologies in both developed and developing countries.

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Box 2: References on the 2˚C target assumption

For the purposes of this report we have focused on a range of emissions reductions for Annex I parties consistent with the goal of maintaining a medium likelihood of keeping the global average temperature rise limited to 2˚C. How do we assess what reductions are necessary to meet this goal?

-IPCC AR4, WGIII, Table SPM.5 (indicating a temperature rise of 2.0 to 2.4 for the concentration range of 445-490ppm CO2-eq)

-IPCC AR4, WGI, Table TS.5 (Stabilization at 450 ppm CO2-eq would result in a temperature "likely in the range" of 1.4-3.1 degrees, with a "best estimate" of 2.1 degrees rise). (see http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-ts.pdf, page 66)

-Elzen & Höhne, op. cit. (Annex I reductions of 30% and non-Annex I deviation of about 17% are necessary for stabilization at 450ppm)

-Parry et al. 2008: Squaring up to reality. Nature. May 2008 (Reducing emissions by 80% by 2050 and stabilizing emissions between 400-485ppm Co2-eq would provide an 80% chance of staying below 2 degrees)

-Hansen et al. Target Atmospheric CO2: Where Should Humanity Aim? (Reducing atmospheric CO2 to at least 350ppm Co2 (=445Co2-eq) is necessary to avoid dangerous anthropogenic interference with the climate)

- Hare, W.L., 2009. A Safe Landing for the Climate, State of the World 2009 (Chapter 2) by The World Watch Institute (A 2 degrees rise is not a safe level and poses dangerous anthropogenic interference with the climate)

Appendix A Model Numerical Specification

Table 3 Baseline emissions and scenario targets (Anger et al., 2009, Anger correspondence)

<table>
<tr><th></th><th></th><th colspan="2">Baseline</th><th colspan="2">Base case - stated targets</th><th>25% reduction vs. 1990</th><th>30% reduction vs. 1990</th><th>40% reduction vs. 1990</th></tr>
<tr><th></th><th>Region</th><th>CO_2 emissions in 1990 (Mt CO_2)</th><th>CO_2 emissions in 2020 (Mt CO_2)</th><th>Reduction in 2020 (% vs. 1990)</th><th>Reduction in 2020 (% vs. 2020)</th><th>Reduction in 2020 (% vs. 2020)</th><th>Reduction in 2020 (% vs. 2020)</th><th>Reduction in 2020 (% vs. 2020)</th></tr>
<tr><td rowspan="21">Annex I Regions</td><td>Austria</td><td>59.6</td><td>74.1</td><td>24.3</td><td>39.1</td><td rowspan="21">33.6</td><td rowspan="21">38.0</td><td rowspan="21">46.9</td></tr>
<tr><td>Belgium</td><td>110.1</td><td>143.9</td><td>19.6</td><td>38.5</td></tr>
<tr><td>Denmark</td><td>50.4</td><td>59.1</td><td>31.3</td><td>41.4</td></tr>
<tr><td>Finland</td><td>54.2</td><td>65.2</td><td>13.0</td><td>27.7</td></tr>
<tr><td>France</td><td>377.3</td><td>421.0</td><td>13.0</td><td>22.1</td></tr>
<tr><td>Germany</td><td>988.3</td><td>963.0</td><td>31.3</td><td>29.5</td></tr>
<tr><td>Greece</td><td>75.8</td><td>106.1</td><td>-8.7</td><td>22.3</td></tr>
<tr><td>Ireland</td><td>33.0</td><td>49.8</td><td>1.7</td><td>34.9</td></tr>
<tr><td>Italy</td><td>417.5</td><td>511.7</td><td>18.7</td><td>33.7</td></tr>
<tr><td>Netherlands</td><td>158.5</td><td>201.8</td><td>18.3</td><td>35.8</td></tr>
<tr><td>Portugal</td><td>43.6</td><td>74.7</td><td>-10.4</td><td>35.6</td></tr>
<tr><td>Spain</td><td>225.8</td><td>351.1</td><td>0.0</td><td>35.7</td></tr>
<tr><td>Sweden</td><td>49.8</td><td>49.8</td><td>9.6</td><td>9.6</td></tr>
<tr><td>United Kingdom</td><td>577.4</td><td>646.5</td><td>23.9</td><td>32.0</td></tr>
<tr><td>Eastern Europe</td><td>1042.1</td><td>1110.4</td><td>8.8</td><td>14.4</td></tr>
<tr><td>EU-27</td><td>4263.4</td><td>4828.1</td><td>20.0</td><td>27.2</td></tr>
<tr><td>Canada</td><td>482.5</td><td>697.7</td><td>2.8</td><td>25.7</td></tr>
<tr><td>Japan</td><td>1106.0</td><td>1186.7</td><td>-13.8</td><td>4.7</td></tr>
<tr><td>Former Soviet Union</td><td>3752.0</td><td>2877.9</td><td>33.2</td><td>0.0</td></tr>
<tr><td>Pacific OECD</td><td>311.8</td><td>475.5</td><td>-3.5</td><td>26.0</td></tr>
<tr><td>United States</td><td>5092.5</td><td>6892.4</td><td>7.8</td><td>26.1</td></tr>
<tr><td rowspan="5">CDM Regions</td><td>Brazil</td><td>214.0</td><td>838.2</td><td colspan="5" rowspan="5">No targets are assumed for CDM regions</td></tr>
<tr><td>China</td><td>2495.7</td><td>6491.2</td></tr>
<tr><td>India</td><td>616.1</td><td>2934.5</td></tr>
<tr><td>Mexico</td><td>309.0</td><td>733.7</td></tr>
<tr><td>South Korea</td><td>253.7</td><td>853.0</td></tr>
</table>

Table 4 Marginal abatement cost functions – Annex I and CDM regions (Anger et al., 2009)

$$-MAC_{ir}(e_{ir}) = \beta_{1,ir}(e_{0ir} - e_{ir}) + \beta_{2,ir}(e_{0ir} - e_{ir})^2 + \beta_{3,ir}(e_{0ir} - e_{ir})^3$$

Region	Energy-intensive sectors (EIS)			Non-energy-intensive sectors (NEIS)		
	$\beta_{1,EIS,r}$	$\beta_{2,EIS,r}$	$\beta_{3,EIS,r}$	$\beta_{1,NEIS,r}$	$\beta_{2,NEIS,r}$	$\beta_{3,NEIS,r}$
Austria	21.1480	-3.3392	0.8094	11.4095	2.8620	-0.1012
Belgium	2.8430	-0.0984	0.0026	5.8176	0.1881	0.0176
Denmark	11.1840	-0.5817	0.0235	59.6656	-12.7515	5.7710
Finland	3.0710	-0.0566	0.0032	75.2956	-14.0624	1.5541
France	0.9439	-0.0078	0.0002	1.5191	0.0784	-0.0007
Germany	0.3668	-0.0017	0.0000	0.9417	0.0111	0.0000
Greece	1.8843	-0.0118	0.0005	30.8964	-1.6083	0.3375
Ireland	3.0683	-0.1585	0.0110	23.4662	-0.3972	0.2788
Italy	0.9413	0.0036	0.0001	2.5992	0.1511	-0.0005
Netherlands	0.8665	0.0393	-0.0004	10.9863	-0.4063	0.1088
Portugal	11.0386	-0.5740	0.0175	56.1921	-9.2007	2.4941
Spain	0.8090	-0.0097	0.0002	10.3924	-0.4192	0.0137
Sweden	7.7433	-0.2814	0.0102	12.5684	1.7070	0.3807
United Kingdom	0.4066	-0.0022	0.0000	1.4731	0.0244	-0.0001
Eastern Europe	0.1466	0.0001	0.0000	0.7554	0.0008	0.0000
Canada	0.2766	0.0007	0.0000	0.8316	0.0044	0.0001
Japan	0.2666	0.0023	0.0000	1.3130	0.0313	-0.0001
Former Soviet Union	0.0218	0.0002	0.0000	0.1075	0.0004	0.0000
Pacific OECD	0.7244	-0.0094	0.0001	1.8636	-0.0315	0.0005
United States	0.0245	0.0000	0.0000	0.1453	0.0000	0.0000
Brazil	11.5525	-0.0631	0.0001	4.1163	0.0006	0.0004
China	0.0129	0.0000	0.0000	0.3052	-0.0004	0.0000
India	0.0960	-0.0001	0.0000	2.2685	-0.0346	0.0008
Mexico	0.0116	0.0191	-0.0001	0.3852	0.0204	-0.0001
South Korea	0.3405	-0.0011	0.0000	4.1598	-0.0027	0.0010

Notes: Polynomial yields price in € 2005 / $MtCO_2$. e_{ir} represents total emissions in sector i region r in 2020. ($e_{0ir} - e_{ir}$) represents emissions reductions from baseline in 2020.

Table 5 Marginal abatement cost function coefficients – rainforest regions

Region	$\beta_{1,r}$	$\beta_{2,r}$	$\beta_{3,r}$
Africa	0.003924	0.00000	0.00000
South-East Asia	0.087960	0.00000	0.00000
Central America	0.055086	0.00000	0.00000
South America	0.020302	0.00000	0.00000

Appendix B Quantitative simulation results

Table 6 Carbon prices by scenario - € 2005 / t CO_2

	BASE CASE	***REDD_ CUR***	***REDD_ SUP20 _ CUR***	***REDD_ SUP50 _ CUR***	***BASE 25PCT***	***BASE 30PCT***	***BASE 40PCT***	***REDD_ 25PCT***	***REDD_ 30PCT***	***REDD_ 40PCT***	***REDD_ SUP20 _ 25***	***REDD_ SUP20 _ 40***	***REDD_ SUP50 _ 25***	***REDD_ SUP50 _ 40***
International Carbon Price	16.05	6.23	12.60	7.78	29.35	34.81	47.76	11.89	14.53	20.35	22.06	34.13	12.95	20.35
REDD Credit Price	-	6.23	2.08	5.20	-	-	-	11.89	14.53	20.35	3.42	4.77	9.09	20.35

Table 7 CDM and REDD volume by scenario- Mt CO_2

		BASE CASE	***REDD_ CUR***	***REDD_ SUP20 _ CUR***	***REDD_ SUP50 _ CUR***	***BASE 25PCT***	***BASE 30PCT***	***BASE 40PCT***	***REDD_ 25PCT***	***REDD_ 30PCT***	***REDD_ 40PCT***	***REDD_ SUP20 _ 25***	***REDD_ SUP20 _ 40***	***REDD_ SUP50 _ 25***	***REDD_ SUP50 _ 40***
REDD	Africa	-	1587	530	1326	-	-	-	2134	2134	2134	871	1215	2134	2134
	SE Asia	-	71	24	59	-	-	-	135	165	231	39	54	103	231
	C. America	-	113	38	94	-	-	-	216	264	318	62	87	165	318
	S. America	-	307	102	256	-	-	-	586	716	1002	168	235	448	1002
	Total REDD	**-**	**2078**	**694**	**1735**	**-**	**-**	**-**	**3071**	**3279**	**3686**	**1140**	**1590**	**2850**	**3686**
CDM	China	1489	562	1185	715	2358	2622	3130	1119	1360	1817	1933	2591	1218	1817
	India	211	72	158	92	457	566	789	148	187	284	315	553	164	284
	Other	111	52	91	62	176	199	247	87	102	134	142	197	93	134
	Total CDM	**1811**	**686**	**1435**	**869**	**2991**	**3387**	**4166**	**1354**	**1649**	**2235**	**2390**	**3340**	**1475**	**2235**

Table 8 Annex I domestic abatement – Mt CO_2

	BASE CASE	***REDD_ CUR***	***REDD_ SUP20_ CUR***	***REDD_ SUP50_ CUR***	***BASE 25PCT***	***BASE 30PCT***	***BASE 40PCT***	***REDD_ 25PCT***	***REDD_ 30PCT***	***REDD_ 40PCT***	***REDD_ SUP20_ 25***	***REDD_ SUP20_ 40***	***REDD_ SUP50_ 25***	***REDD_ SUP50_ 40***
Annex I	1660	707	1342	867	2709	3063	3785	1275	1522	2031	2170	3021	1901	2645

Table 9 Compliance cost and net economic benefit by region and scenario – billion €

	BASE CASE	***REDD_ CUR***	***REDD_ SUP20_ CUR***	***REDD_ SUP50_ CUR***	***BASE 25PCT***	***BASE 30PCT***	***BASE 40PCT***	***REDD_ 25PCT***	***REDD_ 30PCT***	***REDD_ 40PCT***	***REDD_ SUP20_ 25***	***REDD_ SUP20_ 40***	***REDD_ SUP50_ 25***	***REDD_ SUP50_ 40***
Annex I	**41.7**	**19.3**	**27.6**	**19.0**	**123.9**	**165.4**	**276.1**	**59.9**	**82.1**	**139.9**	**78.9**	**167.6**	**53.5**	**139.9**
Africa	-	4.9	0.6	3.4	-	-	-	16.4	22.1	34.5	1.5	2.9	10.5	34.5
SE Asia	-	0.2	0.0	0.2	-	-	-	0.8	1.2	2.4	0.1	0.1	0.5	2.4
C. America	-	0.4	0.0	0.2	-	-	-	1.3	1.9	3.7	0.1	0.2	0.7	3.7
S. America	-	1.0	0.1	0.7	-	-	-	3.5	5.2	10.2	0.3	0.6	2.0	10.2
Total REDD	**-**	**6.5**	**0.7**	**4.5**	**-**	**-**	**-**	**22.0**	**30.4**	**50.7**	**1.9**	**3.8**	**13.7**	**50.7**
China	11.9	1.7	7.3	2.7	37.9	51.6	88.9	6.5	9.7	19.0	22.2	49.8	7.7	19.0
India	1.6	0.2	0.9	0.3	6.0	8.8	17.6	0.8	1.3	2.6	3.2	8.4	1.0	2.6
Other CDM	1.0	0.2	0.6	0.3	2.9	3.9	6.8	0.6	0.8	1.5	1.8	3.8	0.7	1.5
Total CDM	14.5	2.1	8.9	3.3	46.8	64.3	113.4	7.9	11.8	23.2	27.1	62.0	9.4	23.2
Overall	**27.2**	**10.8**	**18.0**	**11.2**	**77.1**	**101.1**	**162.7**	**30.0**	**39.9**	**65.9**	**49.8**	**101.8**	**30.4**	**65.9**

Table 10 Financial transfers – billion €

	BASE CASE	*REDD_ CUR*	*REDD_ SUP20_ CUR*	*REDD_ SUP50_ CUR*	*BASE 25PCT*	*BASE 30PCT*	*BASE 40PCT*	*REDD_ 25PCT*	*REDD_ 30PCT*	*REDD_ 40PCT*	*REDD_ SUP20_ 25*	*REDD_ SUP20_ 40*	*REDD_ SUP50_ 25*	*REDD_ SUP50_ 40*
Annex I	**29.1**	**19.1**	**19.5**	**15.8**	**87.8**	**117.9**	**199.0**	**56.3**	**76.1**	**126.9**	**56.6**	**121.6**	**45.0**	**120.5**
Africa	-	9.9	1.1	6.9	-	-	-	25.4	31.0	43.4	3.0	5.8	19.4	43.4
SE Asia	-	0.4	0.0	0.3	-	-	-	1.6	2.4	4.7	0.1	0.3	0.9	4.7
C. America	-	0.7	0.1	0.5	-	-	-	2.6	3.8	6.5	0.2	0.4	1.5	6.5
S. America	-	1.9	0.2	1.3	-	-	-	7.0	10.4	20.4	0.6	1.1	4.1	20.4
Total	**-**	**12.9**	**1.4**	**9.0**	**-**	**-**	**-**	**36.5**	**47.6**	**75.0**	**3.9**	**7.6**	**25.9**	**75.0**
China	23.9	3.8	14.9	5.6	69.2	91.3	149.5	13.3	19.8	37.0	42.7	88.4	15.8	37.0
India	3.4	0.9	2.0	0.7	13.4	19.7	37.7	2.9	4.1	7.7	6.9	18.9	2.1	5.8
Other CDM	1.8	1.4	1.1	0.5	5.2	6.9	11.8	3.6	4.6	7.2	3.1	6.7	1.2	2.7
Total CDM	29.1	6.1	18.1	6.8	87.8	117.9	199.0	19.8	28.5	51.9	52.7	114.0	19.1	45.5
Overall	**29.1**	**19.1**	**19.5**	**15.8**	**87.8**	**117.9**	**199.0**	**56.3**	**76.1**	**126.9**	**56.6**	**121.6**	**45.0**	**120.5**

Table 11 Price sensitivity by scenario — € 2005 / t CO_2

Sensitivity scenario	*CREDIT TYPE*	*BASE CASE*	*REDD _ CUR*	*REDD _ SUP20 _ CUR*	*REDD _ SUP50 _ CUR*	*BASE 25PCT*	*BASE 30PCT*	*BASE 40PCT*	*REDD _ 25PCT*	*REDD _ 30PCT*	*REDD _ 40PCT*	*REDD _ SUP20 _ 25*	*REDD _ SUP20 _ 40*	*REDD _ SUP50 _ 25*	*REDD _ SUP50 _ 40*
Low supply	International Carbon Price	16.05	8.91	12.60	8.91	29.35	34.81	47.76	14.82	16.97	23.95	22.06	34.13	14.82	23.95
	REDD Credit Price	-	8.91	4.16	8.91	-	-	-	14.82	16.97	23.95	6.84	9.53	14.82	23.95
High supply	International Carbon Price	16.05	3.89	12.60	7.78	29.35	34.81	47.76	7.71	9.69	14.03	22.06	34.13	12.95	18.73
	REDD Credit Price	-	3.89	1.04	2.60	-	-	-	7.71	9.69	14.03	1.71	2.38	4.27	7.68

Note: For any given price, half of the expected delivery of credits occurs under the low-supply scenario. Under the high-supply scenario, twice the expected credits are delivered for any give price.