Climatic Change (2012) 110:523–542
DOI 10.1007/s10584-011-0125-6

Beyond Copenhagen: a realistic climate policy in a fragmented world

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Received: 2 November 2010 / Accepted: 18 May 2011 / Published online: 17 June 2011

Abstract In this paper we argue that the financial provisions of the Copenhagen Accord, if used primarily to mitigate greenhouse gas (GHGs) emissions, could compensate the lack of more energetic action on the domestic mitigation side. In order to maximize the mitigation potential, the Copenhagen Green Climate Fund (CGCF) should be transformed into the International Bank for Emissions Allowance Acquisition (IBEAA) envisaged by Bradford (2008). We estimate that 50 percent of the CGCF in 2020 ($50 billions) could finance from 2.1 to 3.3 Gt CO_2-eq emission reductions, depending on the domestic mitigation effort of Annex I and Non-Annex I countries. We construct a matrix that shows the level of GHGs emissions in 2020 under all possible combinations of abatement pledges and international mitigation financing, thus highlighting a rich set of options to reach the same level of GHGs emissions in 2020.

1 Introduction

As many analysts predicted, the Copenhagen summit held in December 2009 did not achieve the lofty goals that were set for it years ago. It failed to produce a legally binding agreement to substitute the Kyoto Protocol after 2012 (Stavins 2009; Doniger 2009; Tol 2010). But it did make progress. Indeed, a realistic assessment must admit that the outcome of the summit could not have been different. Hopes for a more ambitious result were not based on the reality on the ground. There were and still exist three insurmountable obstacles.

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First, the USA could not sign a binding agreement, as the Senate had not passed the Boxer–Kerry Bill. That bill, coupled with the already approved American Clean Energy and Security Act (Waxman–Markey Bill), would have given President Obama the credibility to propose more ambitious steps (see also Grubb 2010).

Second, the lack of commitment from fast-growing developing countries to reduce emissions—not necessarily immediately, more realistically after a "grace" period—meant that any attempts from developed countries to contain temperature increases to safe levels would have been in vain.

Third, fast-growing developing countries are reluctant to take on any legally binding commitment, citing that their primary objective is to reduce poverty and to spread economic well-being to their poorest citizens. They also point out that responsibility for the high concentrations of greenhouse gases in the atmosphere today is only marginally attributable to their emissions. Hence, their refusal to sign any legally binding agreement, when the major world economies are not ready to do so, is largely understandable.

These are the basic ingredients of the so-called "climate deadlock" that prevented the signing of a real successor to the Kyoto Protocol and pushed the climate summit in Copenhagen to "take note" of a more modest Copenhagen Accord on the morning of Saturday, 19 December 2009.

The Cancun Agreements in December 2010 have anchored the Copenhagen Accord to a Conference of Parties (COP) decision, mainstreaming it into the more solid process of the United Nations Framework Convention on Climate Change (UNFCCC). The pledged emissions reductions have not changed and a legally binding international agreement still seems out of reach. However, progress was recorded on monitoring, on National Appropriate Mitigation Actions (NAMAs) and REDD+.

The possibilities to have a domestic climate change legislation in the US have quickly vanished during the past months and have certainly complicated the negotiation puzzle. However the US difficulties are only part of the problem. Indeed, the "climate deadlock" is the symptom of the present fragmented international climate architecture: countries are willing to take steps towards the reduction of Greenhouse Gases (GHGs), but on a voluntary and uncoordinated basis. The European Union is acting fiercely to recompose the picture in order to reproduce a Kyoto-style, legally-binding agreement with well-defined targets, although without success so far.

There are many reasons to believe that the stall in climate negotiations will not be overcome in the near future. Not only in the COP17 that will be hosted by Durban, South Africa, from November 28 to December 9, 2011, but for several years beyond. It is therefore of the utmost importance to build a realistic climate policy firmly grounded on the actions that countries have unilaterally promised in Copenhagen. The two pillars of climate policy in the years to come are the two important outcomes from Copenhagen. First, a non-binding, but politically relevant, declaration of national emissions targets for 2020. Second, the definition of the resources that will be transferred to developing countries for mitigation and adaptation actions (the Copenhagen Green Climate Fund – CGCF).[1]

[1] Very little progress has been recorded for climate finance at COP 16. A Transitional Committee will submit its guidelines for managing the financial provisions at COP 17.

The primary aim of this paper is to offer guidance to policy makers and negotiators on how to structure efficiently and effectively climate policy in a post-Copenhagen world. We address key issues that will be discussed during the next round of negotiations and will very likely remain at the core of climate policy for several years. We proceed as follows. We start by estimating the level of 2020 emissions implied by the Copenhagen pledges. We argue that comparing the expected level of emissions in 2020 with the level required to achieve the 2°C target might be inconclusive and possibly misleading. A more realistic approach is needed based on what *can* be done rather than on what *should* be done. Therefore, we identify what is feasible and explore the role of international finance to reduce emissions in Non-Annex I countries.

2 What is the effect of the announced Copenhagen targets on global greenhouse gas emissions in 2020?

The Annex I to the Copenhagen Accord[2] contains communications of the parties to the United Nations Framework Convention on Climate Change (UNFCCC) on the voluntary mitigation actions that they intend to put in place to reduce emissions of GHGs in 2020. We have used the UNFCCC Annex I quantified economy-wide emissions targets for 2020 and Annex II nationally appropriate mitigation actions of developing country Parties as source of information. These targets are voluntary, announced in an informal—although public—session on 18 December 2009, or communicated later at the UNFCCC Secretary. While still not legally binding, the commitments announced at Copenhagen are very informative on future climate policies. For this reason any analysis of post-Copenhagen climate policy must start from an assessment of the likely level of GHGs emissions in 2020. Table 1 presents historic and future levels of emissions, with and without the Copenhagen targets, based on our analysis. We estimate emissions for twenty-two countries, covering 75% of global emissions both in 2005 and in 2020.

Quantifying emissions in 2020 for Annex I countries is a straightforward task, because targets are expressed in terms of historic emissions. The only exception is Turkey, that announced its intention to follow its Business as Usual (BaU) scenario for 2020. We compute emissions reduction targets without including emissions from Land Use Land Use Change and Forestry (LULUCF).[3] The future pattern of emissions from LULUCF is instead derived from the Business-as-Usual (BaU) scenario of the WITCH model (Bosetti et al. 2006, 2007, 2009).[4]

[2]Decision 2/CP.15, the "Copenhagen Accord".

[3]GHGs emissions excluding LULUCF for Annex I countries are from the UNFCCC. LULUCF emissions for Annex I countries, and GHGs emissions for Non-Annex I countries—with and without LULUCF—are from IEA (2009). LULUCF emissions scenarios and marginal abatement costs are from the IIASA (International Institute for Applied Systems Analysis) model cluster (Gusti et al. 2008), prepared for the U.K. Office of Climate Change as part of the Eliasch Review (2008).

[4]For a description of WITCH, references and access to scenarios: www.witchmodel.org.

Table 1 Historic emissions, business-as-usual emissions and Copenhagen pledges

Country	Pledge at COP15	Greenhouse gases emissions (GT CO2-eq)[a]									Copenhagen pledges[b]							
		Excluding LULUCF			LULUCF			Total			Target		wrt 1990 (%)		wrt 2005 (%)		wrt BaU (%)	
		1990	2005	2020	1990	2005	2020	1990	2005	2020	LC	HC	LC	HC	LC	HC	LC	HC
Australia[c,d]	−5%, −15% to −25% wrt 2000	0.42	0.53	0.62	0.02	0.02	0.01	0.44	0.54	0.63	0.48	0.37	11%	−15%	−11%	−32%	−23%	−41%
Belarus	−5% /−10% wrt 1990	0.14	0.08	0.10	0.00	0.00	0.00	0.14	0.09	0.10	0.13	0.13	−6%	−11%	56%	48%	29%	22%
Canada	−17% wrt 2005	0.59	0.73	0.83	0.02	0.04	0.04	0.62	0.77	0.88	0.65	0.65	6%	6%	−16%	−16%	−26%	−26%
Croatia	−5% wrt 1990	0.03	0.03	0.04	0.00	0.00	0.00	0.03	0.03	0.04	0.03	0.03	−5%	−5%	−2%	−2%	−20%	−20%
Euro 27	−20% /−30% wrt 1990	5.57	5.12	6.13	0.02	0.01	0.02	5.59	5.13	6.15	4.47	3.91	−20%	−30%	−13%	−24%	−27%	−36%
Iceland	−30% wrt 1990	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	−30%	−30%	−36%	−36%	−44%	−44%
Japan[c]	−25% wrt 1990	1.27	1.35	1.54	0.02	0.02	0.02	1.29	1.38	1.57	0.98	0.98	−24%	−24%	−29%	−29%	−38%	−38%
Kazakhstan[e]	−15% wrt 1992	0.36	0.24	0.26	0.00	0.00	0.00	0.36	0.24	0.26	0.31	0.31	−16%	−16%	29%	29%	18%	18%
New Zealand[c]	−10% to −20% wrt 1990	0.06	0.08	0.09	0.00	0.00	0.00	0.06	0.08	0.09	0.06	0.05	−9%	−19%	−28%	−36%	−37%	−44%
Norway	−30% /−40% wrt 1990	0.05	0.05	0.06	0.00	0.00	0.00	0.05	0.05	0.06	0.03	0.03	−32%	−42%	−36%	−46%	−44%	−52%
Russian Federation[c]	−15% /−25% wrt 1990	3.32	2.12	2.31	0.06	0.04	0.01	3.38	2.16	2.32	2.83	2.50	−16%	−26%	31%	16%	22%	8%
Switzerland	−20% /−30% wrt 1990	0.05	0.05	0.06	0.00	0.00	0.00	0.05	0.05	0.06	0.04	0.04	−23%	−32%	−22%	−31%	−32%	−40%
Turkey	BaU	0.19	0.33	0.40	0.00	0.00	0.00	0.19	0.33	0.40	0.40	0.40	115%	115%	22%	22%	–	–
Ukraine	−20% wrt 1990	0.93	0.42	0.52	0.00	0.00	0.00	0.93	0.42	0.52	0.74	0.74	−20%	−20%	75%	75%	44%	44%
United States	−17% wrt 2005	6.11	7.10	8.23	0.07	0.03	0.00	6.18	7.13	8.23	5.90	5.90	−5%	−5%	−17%	−17%	−28%	−28%
Total Annex I[f]		19.09	18.24	21.20	0.22	0.17	0.11	19.31	18.41	21.31	17.06	16.04	−12%	−17%	−7%	−13%	−20%	−25%
Brazil[c,g]	−0.97/−1.05 Gt CO_2-eq wrt BaU	0.72	1.11	1.53	0.89	1.45	1.13	1.61	2.56	2.66	1.68	1.61	4%	0%	−34%	−37%	−37%	−40%
China[h,i]	Reduce carbon intensity of output by 40–45% wrt 2005	3.72	7.61	10.75	0.04	0.03	−0.28	3.76	7.64	10.47	10.47	10.47	179%	179%	37%	37%	–	–
India[h,j]	Reduce carbon intensity of output by 20–25% wrt 2005	1.33	2.05	2.59	0.05	0.04	0.01	1.38	2.09	2.60	2.60	2.60	89%	89%	24%	24%	–	–
Indonesia[c]	−26% /−41% wrt BaU	0.45	0.73	1.13	0.41	0.84	0.49	0.86	1.57	1.62	1.20	0.96	40%	12%	−24%	−39%	−26%	−41%
Mexico[c]	−51 Mt CO_2-eq/ −30% wrt BaU	0.45	0.61	0.84	0.03	0.04	0.03	0.48	0.65	0.87	0.82	0.61	71%	27%	26%	−6%	−6%	−30%

South Africa[c]	−34% wrt BaU	0.34	0.44	0.51	0.00	0.00	0.00	0.35	0.44	0.51	0.34	0.34	−2%	−2%	−23%	−23%	−34%	−34%
South Korea[c]	−30% wrt BaU	0.30	0.67	0.79	0.00	0.00	0.00	0.30	0.67	0.79	0.55	0.55	84%	84%	−18%	−18%	−30%	−30%
Other Non-Annex I[k]		5.91	7.69	9.59	3.75	2.98	2.00	9.66	10.67	11.59	11.59	11.59	20%	20%	9%	9%	–	–
Total Non-Annex I		13.22	20.90	27.72	5.17	5.40	3.39	18.38	26.30	31.11	29.25	28.72	59%	56%	11%	9%	−6%	−8%
International bunker[l]		0.61	0.94	1.09				0.61	0.94	1.47	1.47	1.47	141%	141%	57%	57%	–	–
World		32.92	40.08	50.01	5.38	5.57	3.50	38.30	45.65	53.90	47.79	46.23	25%	21%	5%	1%	−11%	−14%

[a] This country is part of a wider regional aggregate in the WITCH model. The growth of emissions in the BaU scenario is calculated using the average growth rate of the wider regional aggregate to which the country belongs

[b] We use the increment of GHGs emissions in the WITCH model BaU scenario because the committed reduction of carbon intensity is inferior to the BaU autonomous carbon intensity improvement

[c] Australia's total GHGs emissions were equal to 496 Mt CO_2-eq in 2000

[d] Kazakhstan is a Party included in Annex I for the purposes of the Kyoto Protocol in accordance with Article 1, paragraph 7, of the Protocol, but is not a Party included in Annex I for the purposes of the Convention. The base year is 1992 for Kazakhstan. We estimate 1992 total GHGs emissions based on 1992 CO_2 emissions from CDIAC

[e] Targets of Annex I countries do not consider emissions from LULUCF. Minor countries are not included

[f] China also committed to increase the share of non-fossil fuels in primary energy consumption to around 15% by 2020 and to increase forest coverage by 40 million hectares and forest stock volume by 1.3 billion cubic meters by 2020 from the 2005 levels

[g] Brazil has announced specific mitigation measures. They correspond to GHGs emissions reductions of, respectively, −36.1% and −38.9% wrt the official BaU scenario. Here we use WITCH BaU scenario, which is very close to the official one

[h] The emissions from the agriculture sector will not be part of the assessment of emissions intensity of India

[i] We assume that Other Non-Annex I countries will follow their BaU pattern of emissions

[j] WITCH does not account for international bunkers explicitly. We have projected the level of emissions from international bunkers using the 2000–2005 growth rate

[k] Source of data for GHGs emissions excluding LULUCF in Annex I countries is the UNFCCC. LULUCF emissions in Annex I countries and GHGs emissions in Non-Annex I countries—including and excluding LULUCF—are from IEA (2009)

[l] Future emissions are authors' calculations based on BaU scenarios of the WITCH model. We use the UNFCCC Annex I quantified economy-wide emissions targets for 2020 and Annex II Nationally appropriate mitigation actions of developing country Parties as source of information

Some Annex I countries have announced two targets. We have therefore distinguished between a Low and a High Commitment level (LC and HC henceforth).[5] The HC is usually conditional on other regions collectively taking aggressive action to reduce GHGs emissions.

GHGs emissions in Annex I countries as a group—excluding LULUCF emissions—were equal to 19 Gt CO_2-eq in 1990, they declined to 18.2 Gt CO_2-eq in 2005. If no action is taken to reduce GHGs we expect emissions to be 21.2 Gt CO_2-eq in 2020.[6] Combining the Copenhagen pledges and the expected pattern of emissions from LULUCF we estimate that emissions will be 17 Gt CO_2-eq in the LC scenario and 16 Gt CO_2-eq in the HC scenario.[7] In the LC case emissions will be 12% lower than in 1990 and 7% lower than in 2005. In the HC case emissions will be 17% lower than in 1990 and 13% lower than in 2005.

Instead of announcing emissions targets with respect to a specific base year, Non-Annex I countries have generally taken a more flexible approach. A group of countries has expressed the intention to reduce emissions below the BaU scenario (Indonesia, Mexico, South Africa, South Korea,…).

In order to quantify the Copenhagen pledges of the Non-Annex I group we focus on the pledges announced by six major emitters (60% of Non-Annex I emissions) and we assume that the other countries will follow their BaU scenario. As a group, the Copenhagen commitments would imply 29.2 Gt CO_2-eq of emissions in the LC case and 28.7 Gt CO_2-eq in the HC case (including LULUCF). The expected level of emissions represents a contraction of −6% (LC) and −8% (HC) with respect to the BaU scenario. If compared to 1990, emissions would increase instead by 59% (LC) and 56% (HC). Compared to 2005 the increment would be less dramatic, equal to 11% (LC) and 9% (HC).

The quantified emissions targets of China and India deserve a comment. We find that both countries would achieve their Copenhagen targets as the consequence of autonomous efficiency improvements, triggered by long-term price and technology dynamics, more than by a specific mitigation policy. The BaU scenario of the WITCH model shows an autonomous contraction of the carbon intensity of output equal to 57% for China and equal to 45% for India, with respect to 2005 (for a wider discussion see Carraro and Tavoni 2010; Massetti 2011; Carraro and Massetti 2011).[8] Since the two targets do not appear to be binding, in Table 1 we have set 2020 emissions for China and India equal to their BaU scenario.[9]

[5]For those countries that have an intermediate level of commitment we consider only the two extremes.

[6]The "20-20-20" European Union policy is not part of our BaU scenario.

[7]Using IEA 1990 GHGs emissions—excluding LULUCF—emissions in the HC pledge would be equal to 15.6 Gt CO_2-eq. In the LC pledge emissions would be equal to 16.6 Gt CO_2-eq. Different data sources for 1990 imply roughly ±0.4 Gt CO_2-eq in 2020.

[8]GHGs intensity of India's GDP declines by 51% in 2020 with respect to 2005 in the WITCH BaU scenario.

[9]Both the Energy Information Administration (EIA) and the International Energy Agency (IEA) expect a contraction of carbon intensity equal to 47% in China, in 2020 compared to 2005. For India, the EIA and the IEA see a contraction of carbon intensity of 2020 relative to 2005 equal to 52% and 46%, respectively. Therefore, for both the IEA and the EIA the intensity targets of China and India are already reached in a reference scenario.

Globally, we expect GHGs emissions to be equal to 47.8 Gt CO_2-eq in the LC case and 46.2 Gt CO_2-eq in the HC case. This represents a contraction of emissions of 11% (LC) and 14% (HC) with respect to the BaU. However, emissions still increase, not only with respect to 1990 (+25% in LC and +21% in HC) but also with respect to 2005 (+5% in LC and +1% in HC).

This first analysis of the Copenhagen pledges conveys some important policy messages. First, there are high chances that emissions of GHGs will not be lower than 2005. This is not good news if we expect emissions to start declining at a fast pace in the near future. However the efforts will not be vain. Emissions are expected to depart from their BaU pattern in 2020, at the end of a decade that will very likely continue to see the fast growth of the most dynamic emerging economies, with millions of people lifted out of poverty and hungry for energy. The level of commitment registered at Copenhagen is perhaps not as high as some had wished, but it cannot be judged negligible. Second, policy makers and negotiators should avoid harsh confrontations on the level of commitment: moving from low to high pledges does not bring us much closer to the desired abatement level. Equivalently, unilateral moves to a HC target appear ineffective in controlling global warming.

Our estimates tend to be slightly lower than in other studies, mainly due to different assumptions on LULUCF emissions in the BaU, and to a different level of BaU emissions in Non-Annex I countries. Most studies found that emissions in the HC case will be roughly equal to 48 Gt CO_2-eq, while we expect them to be equal to 46.2 Gt CO_2-eq. Estimates of emissions in the LC case range from 49.2 to 55 Gt CO_2-eq in the literature while we expect them to be 47.8 Gt CO_2 (Dellink et al. 2010; den Elzen et al. 2010; Lowe et al. 2010; Höhne et al. 2010; Houser 2010; Stern and Taylor 2010).[10]

3 Are the promised emissions reductions sufficient to control global warming?

Scientific consensus states that severe climate change cannot be avoided unless we limit the earth's average temperature rise to something like below 2°C. Specifically, the goal announced by the "Group of eight" (G8) and the Major Economies Forum (MEF) in L'Aquila in July 2009 and also mentioned in the Copenhagen Accord, is to keep average temperature to no more than 2.0°C above the pre-industrial level, by 2100. The Copenhagen Accord also mentions the necessity to explore possible ways to constrain temperature increase below 1.5°C.

The GHGs emissions stabilisation scenarios presented in the Fourth Assessment Report (FAR) of the International Panel on Climate Change (IPCC 2007) show that this will require GHGs emissions to: (a) peak before 2015, (b) decrease by roughly 5–10% starting from 2020 (c) then decline steadily. In particular, the UNFCCC prescribes a contraction of Annex I emissions from −25% to −40% with respect to 1990 and Non-Annex I emissions should be −15% to −30% below BaU.

A recent review of the post-FAR literature has found that 2020 emissions of GHGs should be in the range of 39–44 Gt CO_2-eq to meet the 2°C target with a

[10] It must be noticed that many of the estimates in the literature are very similar because they have been generated using the same BaU scenario produced by the IEA.

likely chance (UNEP 2010). Nicholas Stern has fixed a "climate responsible target" of 44 Gt CO_2-eq in 2020 (Stern and Taylor 2010). van Vuuren et al. (2009) find that emissions in 2020 should fall in the range of 44 to 46 Gt CO_2-eq to attain the 2°C target at the end of the century. Therefore, even in the optimistic HC scenario, we estimate that emissions in 2020 will be above the threshold that the literature has found to be compatible with the 2°C target.

Controlling whether emissions in 2020 will be in the range indicated by the literature to achieve the 2°C target is certainly an informative comparison. However, it is misleading to assess a very long-term temperature target on action taken to reduce emissions in the short-term. The level of emissions in 2020 is an important indicator of how strong the commitment is to move forward with mitigation action, but the implications in terms of long-term temperature rise are overshadowed by what will be done after 2020. We briefly explain here why this is the case.

Recent work has shown that the contribution to global warming caused by anthropogenic CO_2 emissions can be directly related to cumulative emissions of carbon dioxide (NRC 2011).[11] Global mean temperature is basically a linear function of the stock of carbon in the atmosphere. This direct link between concentrations and temperature suggests thinking in terms of "carbon budget". This budget can be "spent" with a certain freedom over time. If the temperature target must be met with a chance higher than 95%, the carbon budget for the future is equal to 1,000 Gt CO_2. If we are willing to accept that the probability of achieving the 2°C target is just above 50%, the carbon budget increases to 2,000 Gt CO_2. If the probability decreases to just below 50% the carbon budget increases up to 3,000 Gt CO_2 (NRC 2011; Tavoni et al. 2010). This means that, without mitigation policy, according to the WITCH BaU scenario, the budget would be exhausted in 2030 in the high probability case, in 2045 in the just above 50% case or in 2060 in the just below 50% case.[12]

It is therefore clear that, although not even mentioned in the text of the Copenhagen Accord, the probability with which the international community wants to achieve the 2°C target is by far the most important missing piece of information to test whether we are on the right or wrong track towards the long-term goal. Let us assume, however, that there is consensus to reduce to the minimum the probability not to achieve the 2°C target.[13] When do we spend the remaining 1,000 Gt CO_2?

Tavoni et al. (2010) estimate that a minimum budget of 2,000 Gt CO_2 emissions is needed to allow a fair growth of Non-Annex I countries[14] and a floor of emissions

[11] We are not considering other GHGs because their lifetime is much shorter than for CO_2 and their warming effect is therefore transitory. Increasing the natural absorption capacity of carbon dioxide by means of afforestation, combined use of biomass and carbon capture and storage or other artificial methods would relax the budget. Geoengineering would instead not affect the stock of GHGs in the atmosphere but would reduce the temperature increase.

[12] WITHC model BaU scenario.

[13] With lower probability the carbon budget is sufficiently large to relieve the pressure on short term targets.

[14] For Non-Annex I countries: 1,500 Gt would allow 15 Gt of emissions per year over 100 years. This long-term level of emissions would be 60% lower than BaU emissions of Non-Annex I countries in 2050, according to WITCH.

in Annex I countries.[15] It is therefore necessary to absorb about 1,000 Gt of carbon dioxide from the atmosphere and to store it in forests or underground, by means of bio-energy with carbon capture and sequestration (BECCS). Without net negative global emissions of carbon dioxide, the 2°C target can be achieved only with a probability just below 50%. This simple, back-of-the-envelope calculation is confirmed by a wide range of scenarios produced by the IAM community (Clarke et al. 2009): without net negative emissions on a gigantic scale (roughly 40 years of emissions), it is not possible to achieve the 2°C target with a sufficiently high probability. Unfortunately, we still know very little about the possibility to manage a global carbon dioxide sequestration project. We know very little about the costs, the policy challenges, the technological feasibility and the repercussions on ecosystems of what looks closer to geo-engineering than to mitigation action (see also Carraro and Massetti 2009). The few IAMs scenarios that have shown a feasible pattern of emissions to achieve the 2°C target with high probability rely on speculative assumptions on costs, technical availability and feasibility of net negative emissions beyond 2050 (see Clarke et al. 2009; Tavoni and Tol 2010). These results are informative, but fragile.

It is therefore clear that a few extra Giga tonnes of carbon dioxide in 2020 do not much affect the chances to achieve the 2°C target. Even if we assume inertia in mitigation action, the level of carbon dioxide emissions in 2020 has modest implications on the long term temperature target. For remaining below 2°C with high probability what really matters is the possibility to absorb carbon dioxide at an unprecedented scale. Policy makers should be aware of this important caveat. More attention should be paid to defining the range of probability within which the international community wants to meet the 2°C target, and to studying the possibility of realizing negative emissions on a vast scale. Without more information on these two key issues any evaluation of future targets on the basis of present action is highly speculative.

For these reasons, we do not make heroic assumptions to extrapolate temperature targets from the estimated level of 2020 emissions, as many other studies have done. We would only add uncertainty on top of uncertainty. Also, we do not focus on measuring the "gap" between the projected emissions and a desired target. Rather, we take stock of what is the present politically achievable level of commitment and we suggest an effective way to push forward the climate agenda. The focus is on what can be done, rather than on what should be done.

Policy makers and negotiators should avoid harsh confrontation on the level of commitment in the next rounds of negotiations. It is not the right time to renegotiate targets. The Copenhagen pledges are a sufficiently good starting point. If combined with an efficient allocation of the funding provisions of the Accord there are high chances to achieve non-negligible emissions reductions and to start a long-term trend towards a low-carbon world. In the next Section we propose a sensible approach to the use of the funding provisions of the Accord employing a consistent set of scenarios produced by the WITCH model.

[15]For Annex I countries: 500 Gt would allow 5GTon of emissions per year over 100 years. This long-term level of emissions would be 80% lower than BaU emissions of Annex I countries in 2050, according to WITCH.

4 Financing mitigation action in Non-Annex I countries

The main commitment contained in the Copenhagen Accord is to set up a fast track fund that will consist of $10 billion per year from 2010 to 2012 (totalling $30 billion). If there is sufficient and transparent action towards mitigation, developed countries have committed to mobilise, jointly, $100 billion dollars a year by 2020.[16] A significant portion of such funding will flow through a newly established Copenhagen Green Climate Fund (CGCF).[17]

Recent research with an enhanced version of the WITCH model—designed to quantify the optimal time profile of investments in adaptation and in mitigation—clearly shows that it is optimal to invest immediately in mitigation actions, while delaying most investments in adaptation to the future (Bosello et al. 2009). The reason is that it is imperative to control greenhouse gas emissions as soon as possible to attain low-temperature targets, while the short-term climate change impacts are still moderate and given that adaptation measures can be put in place relatively quickly in the future.

We therefore suggest that the financial resources mobilised in Copenhagen should be used primarily to mitigate greenhouse gas emissions. The CGCF could be transformed into the International Bank for Emissions Allowance Acquisition (IBEAA) envisaged by Bradford (2008). The resulting climate architecture would not follow a pure "purchase of a global public good approach" (Bradford 2008) because there would still be a multilateral, non-binding but official, set of emissions reductions pledges that countries need to fulfil. The second difference is that the CGCF is meant to finance adaptation and mitigation in Non-Annex I countries alone, while the IBEAA proposed by Bradford (2008) has a global scope. The resulting climate architecture would be similar to the "No Cap but Trade" proposal put forward by Tol and Rehdanz (2008) and proposed again in Tol (2010).

Let us move a step forward and quantify what the potential impact of the CGCF would be on emissions in 2020, assuming different allocations of funds between mitigation and adaptation. We estimate cumulative abatement potential in 2020 using scenarios produced by the WITCH model. The mitigation mix includes energy efficiency measures, fuel switching, a new mix in electricity generation, reduction of non-CO_2 gases and avoided deforestation. The right balance of the mitigation mix is endogenously determined in WITCH by taking into consideration a range of interaction channels among countries and a future path of carbon prices. The estimated mitigation potential is therefore consistent with long-term action to reduce global warming.[18] The advantage of our approach is that we can use a consistent set of scenarios to study BaU emissions, to estimate the Copenhagen pledges and to assess the mitigation potential.

[16] It has not been specified what the level of funding would be between 2012 and 2020.

[17] It has not yet been decided what fraction of the total funding will flow trough the CGCF. For simplicity, in the discussion that follows we assume that the CGCF will distribute all international funding promised in the Copenhagen Accord.

[18] We have run three GHGs tax scenarios to have three different levels of abatement in 2020. We have then used the scenarios off-line to estimate the mitigation potential in each region and sector. The starting level for the taxes in 2020 is $10, $30 and $50. The taxes grow at 5% per year afterwards.

Table 2 displays the abatement potential for different categories of cost, with regional and sectoral detail. Our scenarios show that Non-Annex I countries have an abatement potential of 7.9 Gt of CO_2-eq at a cost lower than \$50 per tonne. REDD (2.9 Gt) and the power sector (2.9 Gt) contribute to more than 70% of the abatement effort. The contraction of non-CO_2 gases plays a crucial role in our scenario, contributing to 1.6 Gt of emissions reductions. Fossil fuels emissions reductions in the non-power sector play instead a marginal role because they are relatively more expensive.

Mitigation opportunities are concentrated in China and in the regional aggregate Latin America and the Caribbean (LACA). China has a large potential to reduce emissions from the power sector and emissions from non-CO_2 gasses and no role from REDD. REDD contributes instead to 80% of emissions reductions in LACA. India has a large potential in the power sector. Middle East and Northern Africa (MENA) and South Asia (SASIA) have limited abatement potential, with a relatively important role for non-CO_2 gases emissions. Sub-Saharan Africa (SSA) and

Table 2 Mitigation potential in Non-Annex I countries: sectoral and regional disaggregation

	MENA	SSA	SASIA	CHINA	EASIA	LACA	INDIA	NA1
<\$10								
Fossil fuels - power sector	0.019	0.008	0.001	0.584	0.069	0.029	0.162	0.873
Fossil fuels - non-power	0.029	0.003	0.003	0.034	0.018	0.023	0.010	0.120
Non-CO_2 gases	0.084	0.120	0.041	0.557	0.078	0.178	0.055	1.114
REDD	0.000	0.183	0.000	0.000	0.238	0.788	0.000	1.210
Total	0.132	0.315	0.046	1.174	0.403	1.019	0.228	3.317
>\$10 and <\$30								
Fossil fuels - power sector	0.033	0.014	0.003	0.789	0.090	0.056	0.200	1.187
Fossil fuels - non-power	0.058	0.007	0.006	0.136	0.032	0.047	0.019	0.305
Non-CO_2 gases	0.014	0.033	0.009	0.147	0.020	0.047	0.010	0.280
REDD	0.000	0.037	0.000	0.000	0.220	1.265	0.000	1.522
Total	0.105	0.091	0.018	1.072	0.363	1.416	0.229	3.294
>\$30 and <\$50								
Fossil fuels - power sector	0.048	0.008	0.004	0.399	0.072	0.039	0.124	0.693
Fossil fuels - non-power	0.084	0.009	0.008	0.018	0.049	0.067	0.027	0.263
Non-CO_2 gases	0.008	0.026	0.005	0.050	0.018	0.039	0.009	0.156
REDD	0.000	0.018	0.000	0.000	0.037	0.128	0.000	0.183
Total	0.140	0.062	0.018	0.467	0.175	0.273	0.160	1.295
<\$50								
Fossil fuels - power sector	0.101	0.030	0.009	1.772	0.230	0.124	0.487	2.753
Fossil fuels - non-power	0.170	0.019	0.018	0.188	0.099	0.138	0.055	0.687
Non-CO_2 gases	0.106	0.180	0.056	0.754	0.116	0.264	0.074	1.551
REDD	0.000	0.238	0.000	0.000	0.495	2.182	0.000	2.915
Total	0.377	0.468	0.082	2.713	0.941	2.708	0.617	7.906

Abatement potential is measured in Gt CO_2-eq. NA1 stands for Non-Annex I. We estimate the abatement potential in NA1 countries running three global GHGs tax scenarios. The scenarios do not include the Copenhagen pledges. The tax is on all GHGs and includes emissions from LULUCF. The three taxes start at \$10, \$30 and \$50 at 2020 and increase by 5% per year thereafter. Tax revenues are recycled lump-sum into the economies. The NA1 aggregate does not include South Korea and South Africa. Their pledged emissions reductions are close to the abatement potential in the price range that we study and therefore can be separated from the rest of NA1 countries. The WITCH model regions are: Middle East and South Africa (MENA), Sub-Saharan Africa (SSA), South Asia (SASIA), China, South East-Asia (EASIA), Latin America and the Caribbean (INDIA), India

South East Asia (EASIA) are the two other areas in the world in which REDD plays a major role in reducing emissions.

It is important to recognize that mitigation opportunities in Non-Annex I countries depend on domestic targets and on the number of international offsets (which is influenced by the level of effort in Annex I countries). For this reason we estimate first how many Gt of CO_2-eq can be sponsored by the CGCF and at what cost, under different levels of commitments, as displayed in Table 3. We start by subtracting from the mitigation potential (Table 2) an amount of emissions reductions which corresponds to the domestic pledge. Then, we assume that Annex I countries always cover 20% of the domestic abatement target by means of offsets in Non-Annex I countries. The mitigation potential that we consider is therefore net of international offsets to meet the Copenhagen pledges.

A first analysis of Table 3 reveals that if Non-Annex I countries follow their BaU pattern of emissions, there are 8.3–8.5 Gt CO_2-eq of mitigation potential in Non-Annex I countries at a cost below \$50 per tonne of CO_2-eq. Higher effort to reduce emissions in Annex I countries—at a constant level of effort in Non-Annex I countries—reduces the amount of mitigation that can be financed via the CGCF because the demand for offsets increases. Also, higher effort from Non-Annex I countries—at constant level of effort in Annex I countries—reduces the number of available mitigation projects that can be financed by international donors.

Figure 1 shows how large the impact of the CGCF on global emissions efforts can be with different combinations of commitment and with allocation rules for the CGCF. In case of high commitment (A1 HC–NA1 HC), 50% of the CGCF in 2020 would allow to reduce global emissions by a further 2.5 Gt CO_2-eq; with a more relaxed level of commitment (A1 LC–NA1 BaU) the same amount of emissions reductions could be financed with only 25% of the CGCF for mitigation.

An interesting question for policy makers is in what regions and in what sectors it would be optimal to direct the CGCF. Table 4 reports the regional and sectoral distribution of the CGCF, when both Annex I countries and Non-Annex I countries take on the low-commitment pledge (A1 LC–NA1 LC). The largest share of emissions reductions is available in China. Despite the large mitigation potential in EASIA and in LACA, the ambitious pledges of Indonesia, Mexico and Brazil rapidly exhaust all cheap domestic abatement potential. China and India are the areas in which traditional, CDM-type, emissions reductions are possible. LACA is the place to invest in REDD, followed by SSA and EASIA. From a sectoral perspective,

Table 3 Mitigation potential in Non-Annex I countries, at different costs, with different assumptions on the level of commitment, excluding offsets from Annex I countries

Annex I—high commitment				Annex I—low commitment			
Cost of abatement	Non-Annex I commitment			Cost of abatement	Non-Annex I commitment		
	High	Low	BaU		High	Low	BaU
<\$10	1.3	1.3	2.3	<\$10	1.4	1.4	2.5
>\$10 and <\$30	2.3	2.8	4.7	>\$10 and <\$30	2.4	2.9	4.7
>\$30 and <\$50	1.3	1.3	1.3	>\$30 and <\$50	1.3	1.3	1.3
<\$50	4.9	5.4	8.3	<\$50	5.1	5.6	8.5

We assume that Annex I countries cover 20% of their Copenhagen pledges target using international offsets. The abatement potential shown here is net of international offsets to meet the Copenhagen pledges

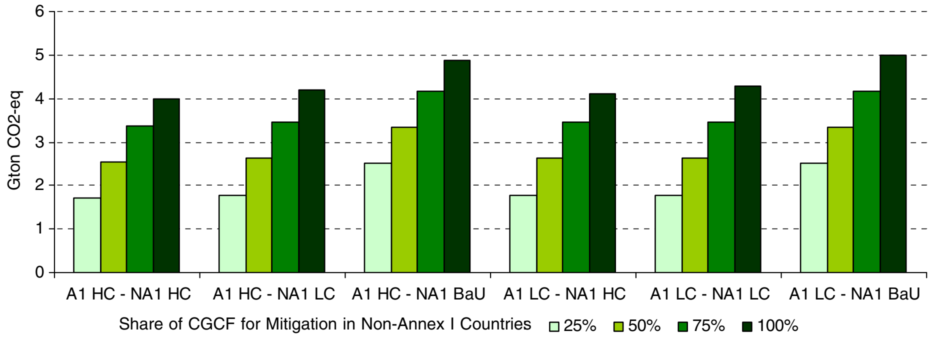

Fig. 1 International offsets available under alternative schemes of the CGCF and alternative commitment levels of Annex I and Non-Annex I countries

two thirds of the abatement potential of the CGCF is from increased efficiency, fuel-switching and decarbonization of the power sector, and from a sharp contraction of non-CO_2 gases. Abatement costs in the non-power sector—mainly oil for

Table 4 The regional and sectoral distribution of mitigation potential in Non-Annex I countries when 50% of the CGCF is used for mitigation

	MENA	SSA	SASIA	CHINA	EASIA	LACA	INDIA	NA1
A1 LC - NA1 LC								
Fossil fuels - power sector	0.024	0.008	0.002	0.707	0.021	0.017	0.197	0.975
Fossil fuels - non-power	0.037	0.003	0.003	0.059	0.007	0.014	0.013	0.136
Non-CO2 gases	0.081	0.105	0.037	0.556	0.013	0.044	0.055	0.891
REDD	0.000	0.158	0.000	0.000	0.060	0.399	0.000	0.617
Total	0.142	0.274	0.042	1.322	0.100	0.473	0.265	2.619
A1 LC - NA1 LC - No REDD								
Fossil fuels - power sector	0.031	0.023	0.002	0.896	0.000	0.000	0.249	1.201
Fossil fuels - non-power	0.049	0.010	0.004	0.087	0.000	0.000	0.018	0.168
Non-CO_2 gases	0.088	0.200	0.037	0.619	0.000	0.000	0.061	1.005
REDD	–	–	–	–	–	–	–	–
Total	0.167	0.233	0.043	1.602	0.000	0.000	0.328	2.374
A1 LC - NA1 LC - only CO_2								
Fossil fuels - power sector	0.080	0.137	0.007	0.853	0.062	0.405	0.097	1.642
Fossil fuels - non-power	0.007	0.023	0.001	0.047	0.012	0.124	0.151	0.364
Non-CO_2 gases	–	–	–	–	–	–	–	–
REDD	0.000	0.000	0.001	0.073	0.005	0.021	0.000	0.099
Total	0.087	0.159	0.009	0.973	0.079	0.551	0.248	2.106
A1 LC - NA1 BaU								
Fossil fuels - power sector	0.019	0.007	0.001	0.556	0.080	0.037	0.155	0.854
Fossil fuels - non-power	0.028	0.003	0.003	0.040	0.022	0.030	0.010	0.136
Non-CO_2 gases	0.071	0.097	0.034	0.479	0.076	0.174	0.048	0.978
REDD	0.000	0.147	0.000	0.000	0.261	0.957	0.000	1.364
Total	0.118	0.253	0.038	1.075	0.439	1.198	0.212	3.333

The allocation of mitigation measures among sectors and regions is obtained by subtracting from the domestic abatement potential the domestic pledge, the international offsets from Annex I countries, and by distributing the fund proportionally to regional and sectoral abatement potential
MENA Middle East and Northern Africa; *SSA* Sub-Saharan Africa; *SASIA* South Asia; *EASIA* East Asia, *LACA* Latin America and the Caribbean; *NA1* Non-Annex I

transport—are typically much higher than in other sectors and therefore account for only a small fraction of the optimal mix.

REDD and abatement of non-CO_2 gases account for 1.5 Gt CO_2-eq—or 58% of emissions reductions in the A1 LC–NA1 LC scenario that we have examined in Table 4. However, it is unquestionable that both REDD and non-CO_2 gases are plagued by serious measurement, reporting and verification problems. Although it is extremely attractive to start protecting the global climate by halting deforestation—a tragic problem in itself—it is sensible to explore the potential of the CGCF if in the next 10 years little progress is made on REDD. It might also be difficult, or costly, to monitor the reduction of non-CO_2 gases, mainly concentrated in agriculture and other industrial processes. For these reasons we have examined the potential of the CGCF in the A1 LC–NA1 LC scenario, under alternative assumptions on the availability of REDD and non-CO_2 gases emissions reductions.

If the CGCF is used to sponsor only fossil-fuels emissions reductions, 0.82 Gt CO_2-eq less of abatement are possible. If the limitation is non-CO_2 gases only and REDD is available, this figure would be reduced to 0.52 Gt CO_2-eq. The impossibility to use REDD while emissions reductions of non-CO_2 gases are possible reduces the scope of the fund by 0.25 Gt CO_2-eq. Despite REDD is globally the most important source of mitigation potential non-CO_2 gases have a greater weight in the CGCF because Brazil and Mexico (in LACA) and Indonesia (in EASIA) absorb the largest share of REDD emissions to cover their domestic pledges (Tables 2 and 4).

It is not clear if the pledged abatement of Non-Annex I countries is conditional on financial assistance from richer countries. It is also not clear if the CGCF will be used to sponsor the pledged emissions cuts of Non-Annex I countries or if it will contain additional finance only. For this reason we have included the possibility that Non-Annex I countries behave following their BaU emissions pathways in Table 3. Table 4 illustrates the sectoral and regional distribution of abatement potential when 50% of the CGCF is used for mitigation and Annex I countries follow a low commitment profile. Since Indonesia, Brazil, Mexico and other non-Annex I countries do not exhaust cheap abatement possibilities to cope with domestic pledges, $50 billions in 2020 can offset 3.34 Gt CO_2-eq. The same amount of financial resources can buy 2.62 Gt CO_2-eq in the A1 LC–NA1 LC scenario. Since Non-Annex I countries have committed to emissions reductions equal to 1.86 Gt CO_2-eq, they could potentially crowd-out 1.1 Gt CO_2-eq of CGCF abatement potential. A share of the CGCF close to 80% would be needed to generate the same level of global emissions reductions that we estimate for the A1 LC–NA1 LC scenario.

Our analysis shows that the same mitigation target can be achieved by many different combinations of domestic pledges and international funding of mitigation. High pledges and international financing of mitigation can be substitute. Given the present climate deadlock the financial provisions of the Copenhagen Accord could compensate the lack of more energetic action on the domestic mitigation side.

We estimate the level of emissions in 2020 that would result from the Copenhagen pledges and from climate finance to illustrate how rich the policy set is. Table 5 contains the key message of our work: many different policy mixes can achieve the same desired level of emissions in 2020. The minimum level of emissions in 2020 is estimated to be equal to 42.2 Gt CO_2-eq; the maximum is 49.6; the level of emissions in 2005 lies at the centre of this range, at 45.6 Gt CO_2-eq. We marked in italics all those combinations in which it is possible to reduce emissions in 2020 below the 2005

Table 5 Global GHGs emissions in 2020 (Gt CO_2-eq) under different policy mixes

Use of the CGCF	Annex I					
	LC Non-Annex I			HC Non-Annex I		
	LC	HC	BaU	LC	HC	BaU
No CGCF	47.8	47.3	49.6	46.8	46.2	48.6
Full						
25%	46.0	*45.5*	47.1	*45.0*	*44.5*	*46.1*
50%	*45.2*	*44.6*	46.3	*44.1*	*43.7*	*45.3*
75%	*44.3*	*43.8*	*45.5*	*43.3*	*42.9*	*44.5*
100%	*43.5*	*43.2*	*44.8*	*42.6*	*42.2*	*43.7*
No Redd						
25%	46.2	45.7		*45.2*	*44.8*	
50%	*45.4*	*44.9*		*44.4*	*44.0*	
75%	*44.6*	*44.0*		*43.6*	*43.1*	
100%	*43.7*	*43.8*		*43.4*	*42.9*	
Only CO_2						
25%	46.5	46.0		*45.5*	*45.0*	
50%	45.7	*45.2*		*44.7*	*44.2*	
75%	*44.8*	*44.3*		*43.8*	*43.4*	
100%	*44.0*	*44.0*		*43.4*	*43.1*	
No REDD and only CO_2						
25%	46.8	46.3		45.8	*45.4*	
50%	46.0	*45.5*		*45.0*	*44.5*	
75%	*45.2*	*44.6*		*44.1*	*43.7*	
100%	*44.3*	*44.6*		*44.2*	*43.7*	
Min 42.2		Median 44.6			Max 49.6	

In *italics* all the policy combinations with emissions below the 2005 level; we underline the combinations that bring emissions in a ±0.5 interval around the 44 Gt CO_2-eq target proposed by Stern and Taylor (2010)

level. We underline those combinations that also allow to achieve the target proposed by Stern and Taylor (2010). This list is by no means exhaustive but it is clear that the number of options is large.

We want to convey the message that policy makers can craft ingenious agreements that circumvent policy difficulties. Focussing on emissions pledges alone can be counterproductive. Stressing what should be done instead of what could be done can also limit the possibilities to move forward in the construction of an effective global climate agenda.

It is important to underline the fact that the main purpose of our study is not to provide an exact quantification of the emissions level in 2020. Our modelling tool is crafted to study long-term economic growth dynamics, which might easily deviate from the business-cycle. The main message of our study, however, is confirmed even if the level of emissions in 2020 is inaccurate: at the centre of the international climate agenda we should find the efficient allocation of political and economic capital to reduce emissions in a long-term perspective rather than the short-term obsession with targets and timetables.

Given the high uncertainty that surrounds the level of emissions from LULUCF more dire scenarios are possible. We refer in particular to the possibility that

LULUCF emissions might have been underestimated due to the omission of emissions from peat land. We explore some of those scenarios in the Appendix.

5 Conclusions

The mitigation targets set in Copenhagen have been anchored to the UNFCCC system by the Cancun Agreements and still represent the major novelty in the climate agenda. In this study we show that they will have a moderate, although non-negligible impact on global emissions in 2020. Emissions will increase by 26–22% with respect to 1990, but they will be 13–16% lower than in the BaU scenario.[19]

The level of emissions that we expect in 2020, even with the highest level of commitment pledged in Copenhagen, will be too high to meet the 2°C target with a likely chance (van Vuuren et al. 2009; UNEP 2010; Stern and Taylor 2010). However, we do not stress in this paper the importance of measuring the "emissions gap". Assessing the safe temperature corridor that would lead to the 2°C target is certainly a useful exercise, but of limited scientific and practical relevance. Recent work from climate scientists surveyed in NRC (2011) shows that, in the long run, global mean temperature responds almost linearly to the stock of total carbon emissions. Therefore it is impossible to make sensible predictions on future temperature by looking only at emissions in the very short run. The uncertainty on the long-term implications of any target on global emissions in 2020 and the very poor chances of an agreement on more ambitious emissions cuts, suggest a shift in the focus of the debate away from what should be done towards what can be done.

To this end, the Copenhagen Green Climate Fund represents a formidable tool to finance investment in the development of low carbon technologies (and their diffusion), in energy efficiency, in avoiding deforestation, in carbon capture and storage technology, etc (see also Bradford 2008; Tol and Rehdanz 2008; Tol 2010).

With this study we estimate the potential of using different shares of the CGCF to finance abatement actions in Non-Annex I countries. The number of cheap abatement options (<\$50 per tonne CO_2-eq) is large enough to reduce emissions by several Gt CO_2-eq in 2020. Although we realize the complexity of managing such widespread offsets schemes, it cannot be denied that there are low-hanging fruits to be picked, especially in the form of reduced emissions from deforestation. For example, 25% of the CGCF in 2020 will enable to scale by a factor of 15 the amount of resources invested by the Forest Carbon Partnership Facility in REDD projects.[20]

Abatement opportunities are concentrated in China and in Latin America. While China's abatement potential mainly consists of measures in the energy sector and curbing emissions of non-CO_2 gasses, the largest potential for REDD is found in Latin America. The impossibility to make progress on REDD or to reduce non-CO_2 gases emissions would considerably limit climate finance potential. It is therefore important to pursue the efforts on measurability, reporting and verification in those sectors.

[19] It is important to note that the simple fact that emissions in 2020 will not be lower than emissions in 2005 does not imply that emissions have not peaked between 2005 and 2020.

[20] The amount of funding at March 2009 was 1.7$ billions (Bosquet et al. 2010).

Our main message is that international financing of mitigation can be a valuable substitute for ambitious pledges. It is possible to expand the feasibility space of future international agreements focussing on all the possible combinations of top-down abatement targets and bottom-up mitigation measures. Table 5 relates the ambition of the emissions targets and the mitigation potential of climate finance providing useful guidelines to policy makers.

Future negotiations should devote greater attention to discussing opportunities to reduce emissions based on what has already been established in the Copenhagen Accord. Trying to renegotiate the targets and fuelling a harsh confrontation on the commitment levels of individual countries will not make the fight against global warming any easier.

Acknowledgements This paper is part of the research work carried out within the Sustainable Development Programme of the Fondazione Eni Enrico Mattei. Financial support from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244766 - PASHMINA (PAradigm SHifts Modelling and INovative Approaches) is kindly acknowledged. The authors are grateful to Massimo Tavoni, Alice Favero and Chiara Rogate and to two anonymous referees for useful comments and suggestions.

Appendix

In this Appendix we discuss with greater detail the methodology followed to estimate le level of emissions of Non-Annex I countries in 2020, including the Copenaghen Pledges. We also discuss alternative scenarios that introduce more pessimistic views on emissions from LULUCF and from international bunkers.

China has a goal to reduce the carbon intensity of Gross Domestic Product (GDP) by 40–45% compared to the 2005 level, to increase the share of non-fossil fuels in primary energy consumption to around 15% in 2020 and to increase forest coverage by 40 million hectares and forest stock volume by 1.3 billion cubic meters by 2020 from 2005 levels. India also has an intensity target of −20%/−25% with respect to 2005, excluding emissions from agriculture. Brazil has quantified specific mitigation actions that range from −0.97 to −1.05 Gt CO_2-eq; when compared to the Brazilian government BaU, this is equivalent to a contraction of emissions of 36.1% and 38.9%, respectively.

Quantifying emissions reductions pledged by Non-Annex I countries is not an easy task. The most important source of ambiguity is the lack of a clear reference. In general, countries have not indicated their expected BaU level of emissions and therefore any assessment of their future level of emissions is subject to a wide margin of uncertainty. Also, many countries have not specified whether the promised emissions cuts will include or exclude LULUCF emissions. Brazil has clearly indicated that part of the mitigation effort will be directed towards the reduction of deforestation and land degradation. But other countries have not been as specific. Moreover, there is still wide uncertainty on the BaU pattern of emissions from LULUCF. Since LULUCF emissions account for 20% of total GHGs emissions in the Non-Annex I group, the uncertainty that surrounds their inclusion in the target and their future BaU pattern are other major sources of ambiguity. Since emissions reductions from avoided deforestation and land degradation (REDD) are among the cheapest options to reduce GHGs emissions, we assume here that all Non-Annex I countries have included emissions from LULUCF in their Copenhagen pledges.

Some caveats apply to our analysis. First, we have used the BaU scenario of the WITCH model to derive the pledges of Non-Annex I countries in 2020. The level of economic activity in WITCH is endogenous and is governed by a Ramsey-type optimal growth model that is suited to study productive capital accumulation in the long-run. With perfect foresight and no uncertainty, the expansion of economic systems follows a smooth path, unable to reproduce short-term fluctuations due to economic crises or booms. Therefore, the actual level of economic activity, and of carbon emissions, in 2020, might well be above or below the long-term pattern of Non-Annex I countries depicted in our scenario.

The second caveat concerns the pattern of emissions from LULUCF. Emissions from LULUCF are exogenous in WITCH and are assumed to decline over time. In the BaU scenario, the contraction of LULUCF emissions accounts for a net reduction of 2 Gt CO_2-eq in 2020, with respect to 2005, mainly concentrated in Non-Annex I countries. If emissions in 2020 from LULUCF will be as high as in 2005, an extra 2 Gt CO_2-eq should be added to our estimates.

The third caveat concerns emissions from fossil fuels displaced in international bunkers, not explicitly modelled in WITCH. Since they are non-negligible in level and are one of the fastest growing sources of carbon emissions, we project emissions in 2020 by applying the same growth rate observed from 2000 to 2005. Any specific action of countries to reduce emissions from international bunkers would bias our estimates upward, or vice versa.

The fourth caveat concerns the possible use of surplus emission allowances or assigned amount units (AAUs), often referred to as "hot air", of Russia and Ukraine. While we do not make here any specific assumption on the future use of AAUs, a recent study has shown that banking and use of surplus AAUs from the first commitment period would add up to 1.5 Gt CO_2-eq to the pledges of Annex I countries (den Elzen et al. 2010).

Finally, the LC and HC cases do not span the whole range of plausible scenarios for 2020 GHGs emissions. The HC seems to be an optimistic scenario. Annex I countries take on the high commitment pledge, Non-Annex I reduce emissions below a BaU scenario that already sees a marked contraction of energy intensity. LULUCF emissions are halved by 2020 and AAUs are not carried over to the future after the first commitment period of the Kyoto Protocol. The LC scenario has slightly higher emissions, but the gap between the two is not large. If we compare these two benchmark cases with two pessimistic alternatives in which emissions from LULUCF in 2020 remain as high as in the present and AAUs are carried over to the future. Emissions in the HC pessimistic scenario are higher than in the LC scenario, meaning that LULUCF emissions and AAUs need careful consideration. More optimistic views on emissions from international bunkers would reduce emissions below the benchmark cases.

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