18. CLIMATE VARIABILITY, CLIMATE MODELS, AND UNCERTAINTIES

Climate exhibits great variability, forced and unforced, which increases with increasing time scale [2, 90, 91]. Increasing abilities to understand the nature of this natural variability and improving modeling abilities [S42] do not diminish the complications posed by chaotic variability for interpretation of ongoing global change.

Expectation that global temperature will continue to rise on decadal time scales is based on a combination of climate models and observations that support the inference that the planet has a positive energy imbalance [5, 8, 96]. If the planet is out of energy balance by +0.5-1 W/m^2, climate models show that global cooling on decadal time scales is unlikely [96], although one model forecast [95] suggests that the Atlantic overturning circulation could weaken in the next decade, causing a regional cooling that offsets global warming for about a decade.

The critical datum for determining the certainty of continued global warming on decadal time scales is the planet's energy imbalance. Improved evaluations of ocean heat storage in the upper 700 m of the ocean [97] yield ~0.5 x 10^{22} J/yr averaged over the past three decades, which is ~0.3 W/m^2 over the full globe. Our model has comparable heat storage in the ocean beneath 700 m, but limited observational analyses for the deep ocean [S43] report negligible heat storage.

If our modeled current planetary energy imbalance of 0.5-1 W/m^2 is larger than actual heat storage, the likely explanations are either: (1) the climate model sensitivity of 3°C for doubled CO_2 is too high, or (2) the assumed net climate forcing is too large. Our paleoclimate analyses strongly support the modeled climate sensitivity, although a sensitivity as small as 2.5 W/m^2 for doubled CO_2 could probably be reconciled with the paleoclimate data. The net climate forcing is more uncertain. Our model [8] assumes that recent increase of aerosol direct and indirect (cloud) forcings from developing country emissions are offset by decreases in developed countries.

These uncertainties emphasize the need for more complete and accurate measurements of ocean heat storage, as well as precise global observations of aerosols including their effects on clouds. The first satellite observations of aerosols and clouds with the needed accuracy are planned to begin in 2009 [98]. Until accurate observations of the planetary energy imbalance and global climate forcing are available, and found to be consistent with modeled climate sensitivity, uncertainties in decadal climate projections will remain substantial.

The sun is another source of uncertainty about climate forcings. At present the sun is inactive, at a minimum of the normal ~11 year solar cycle, with a measureable effect on the amount of solar energy received by Earth (Fig. **S21**). The amplitude of solar cycle variations is about 1 W/m^2 at the Earth's distance from the sun, a bit less than 0.1% of the ~1365 W/m^2 of energy passing through an area oriented perpendicular to the Earth-sun direction.

Climate forcing due to change from solar minimum to solar maximum is about ¼ W/m^2, because the Earth absorbs ~235 W/m^2 of solar energy, averaged over the Earth's surface. If equilibrium climate sensitivity is 3°C for doubled CO_2 (¾°C per W/m^2), the expected equilibrium response to this solar forcing is ~0.2°C. However, because of the ocean's thermal inertia less than half of the equilibrium response would be expected for a cyclic forcing with ~11 year period. Thus the expected global-mean transient response to the solar cycle is less than or approximately 0.1°C.

It is conceivable that the solar variability is somehow amplified, e.g., the large solar variability at ultraviolet wavelengths can affect ozone. Indeed, empirical data on ozone change with the solar cycle and climate model studies indicate that induced ozone changes amplify the direct solar forcing, but amplification of the solar effect is by one-third or less [S45, S46].

Other mechanisms amplifying the solar forcing have been hypothesized, such as induced changes of atmospheric condensation nuclei and thus changes of cloud cover. However, if such mechanisms were effective, then an 11-year signal should appear in temperature observations (Fig. **7**). In fact a very weak solar signal in global temperature has been found by many investigators, but only of the magnitude (~0.1°C or less) expected due to the direct solar forcing.

The possibility remains of solar variability on longer time scales. If the sun were to remain 'stuck' at the present solar minimum (Fig. **S21**) it would be a decrease from the mean irradiance of recent decades by ~0.1%, thus a climate forcing of about -0.2 W/m^2.

The current rate of atmospheric CO_2 increase is ~2 ppm/year, thus an annual increase of climate forcing of about +0.03 W/m^2 per year. Therefore, if solar irradiance stays at its recent minimum value, the climate forcing would be offset by just seven years of CO_2 increase. Human-made GHG climate forcing is now increasing at a rate that overwhelms variability of natural climate forcings.

Climate models are another source of uncertainty in climate projections. Our present paper and our estimated target CO_2 level do not rely on climate models, but rather are based on empirical evidence from past and ongoing climate change. However, the limited capability of models to simulate climate dynamics and interactions among climate system components makes it difficult to estimate the speed at which climate effects will occur and the degree to which human-induced effects will be masked by natural climate variability.

The recent rapid decline of Arctic ice [S47-S49] is a case in point, as it has been shown that model improvements of multiple physical processes will be needed for reliable simulation. The modeling task is made all the more difficult by likely connections of Arctic change with the stratosphere [S50] and with the global atmosphere and ocean [S51].

REFERENCES

[S1] Hewitt C, Mitchell J. Radiative forcing and response of a GCM to ice age boundary conditions: cloud feedback and climate sensitivity. Clim Dyn 1997; 13: 821-34.

[S2] Chylek P, Lohmann U. Aerosol radiative forcing and climate sensitivity deduced from the Last Glacial Maximum to Holocene transition. Geophys Res Lett 2008; 15: L04804, 1-5.

[S3] Schmidt GA, Ruedy R, Hansen JE, *et al.* Present day atmospheric simulations using GISS ModelE: Comparison to in-situ, satellite and reanalysis data. J Clim 2006; 19: 153-92.

[S4] Ingersoll AP. The runaway greenhouse: a history of water on Venus. J Atmos Sci 1969; 26, 1191-98.

[S5] Hoffman PF, Schrag DP. The snowball Earth hypothesis: testing the limits of global change. Terra Nova 2002; 14: 129-55.

[S6] Chandler MA, Sohl LE. Climate forcings and the initiation of low-latitude ice sheets during the Neoproterozoic Varanger glacial interval. J Geophys Res 2000; 105: 20737-56.

[S7] Wunsch C. The spectral description of climate change including the 100 ky energy. Clim Dyn 2003; 20: 353-63.

[S8] Jouzel J, Masson-Delmotte V, Cattani O, *et al.* Orbital and millennial Antarctic climate variability over the past 800,000 Years. Science 2007; 317: 793-6.

[S9] Medina-Elizade, M, Lea DW. The mid-Pleistocene transition in the Tropical Pacific. Science 2005; 310: 1009-12.

[S10] Hansen J, Sato M, Ruedy R, Lo K, Lea DW, Medina-Elizade M. Global temperature change. Proc Natl Acad Sci 2006; 103: 14288-93.

[S11] Lea DW, Pak DK, Spero HJ. Climate impact of late Quaternary equatorial Pacific sea surface temperature variations. Science 2000; 289: 1719-24.

[S12] Lea DW, Pak DK, Belanger CL, Spero HJ, Hall MA, Shackleton NJ. Paleoclimate history of Galapagos surface waters over the last 135,000 yr. Q Sci Rev 2006; 25: 1152-67.

[S13] Saraswat R., Nigam R., Weldeab S., Mackensen A, Naidu PD. A first look at past sea surface temperatures in the equatorial Indian Ocean from Mg/Ca in foraminifera. Geophys Res Lett 2005; 32: L24605.

[S14] Russell GL, Miller JR, Rind D. A coupled atmosphere-ocean model for transient climate change studies. Atmos-Ocean 1995; 33: 683-730.

[S15] Lisiecki LE, Raymo ME. A Pliocene-Pleistocene stack of 57 globally distributed benthic $\delta^{18}O$ records. Paleoceanography 2005; 20: PAI 003.

[S16] Bintanja R, van de Wal RSW, Oeriemans J. Modelled atmospheric temperatures and global sea levels over the past million years. Nature 2005; 437: 125-8.

[S17] Blakey R. Global paleogeographic views of Earth history – Late Precambrian to Recent 2008; http://jan.ucc.nau.edu/~rcb7/globaltext2.html

[S18] Royer DL, Berner RA, Beerling DJ. Phanerozoic atmospheric CO_2 change: Evaluating geochemical and paleobiological approaches. Earth-Science Rev 2001; 54: 349-92.

[S19] Fletcher BJ, Brentnall SJ, Anderson CW, Berner RA, Beerling DJ. Atmospheric carbon dioxide linked with Mesozoic and early Cenozoic climate change. Nature Geosci 2008; 1: 43-8.

[S20] Kurschner WM, Zlatko K, Dilcher DL. The impact of Miocene atmospheric carbon dioxide fluctuations on climate and the evolution of terrestrial ecosystems. Proc Natl Acad Sci 2008; 105: 449-53.

[S21] Cerling TE. Carbon dioxide in the atmosphere: Evidence from Cenozoic and Mesozoic paleosols. Am J Sci 1991; 291: 377-400.

[S22] Gray JE, Holroyd GH, Van der Lee FM, Bahrami AR, Sijmons PC, Woodward FI, Schuch W, Hetherington AM. The HIC signalling pathway links CO_2 perception to stomatal development. Nature 2000; 408: 713-16.

[S23] Woodward FI. Stomatal numbers are sensitive to increases in CO_2 from pre-industrial levels. Nature 1987; 327: 617-8.

[S24] Royer DL. Stomatal density and stomatal index as indicators of paleoatmospheric CO_2 concentration. Rev Palaeobot Palynol 2001; 114: 1-28.

[S25] Woodward FI, Bazzaz FA. The responses of stomatal density to CO_2 partial pressure. J Expert Bot 1988; 39: 1771-81.

[S26] Popp BN, Takigiku R, Hayes JM, Louda JW, Baker EW. The post-Paleozoic chronology and mechanism of 13C depletion in primary marine organic matter. Amer J Sci 1989; 289: 436-54.

[S27] Pagani M. The alkenone-CO_2 proxy and ancient atmospheric CO_2, In Understanding Climate Change: Proxies, Chronology, and Ocean-Atmosphere Interactions. Gröcke DR, Kucera M, Eds. Philos Trans Ro Soc Lond Series A 2002; 360: 609-32.

[S28] Spivack AJ, You C-F, Smith HJ. Foraminiferal boron isotope ratios as a proxy for surface ocean pH over the past 21 Myr. Nature 1993; 363: 149-51.

[S29] Blamart D, Rollion-Bard C, Meibom A, Cuif JP, Juillet-Leclerc A, Dauphin Y. Geochem Geophys Geosyst 2007; 8, 12: Q12001.

[S30] Lemarchand D, Gaillardet J, Lewin É, Allègre CJ. The influence of rivers on marine boron isotopes and implications for reconstructing past pH. Nature 2000; 4008:951-4.

[S31] Pagani M, Lemarchand D. Spivack A, Gaillarde J. A critical evaluation of the boron isotope-pH proxy: The accuracy of ancient ocean pH estimates. Geochimica et Cosmochimica Acta 2005; 69: 953-61.

[S32] Marland G, Boden TA, Andres RJ. Global, regional, and national fossil fuel CO_2 emissions. In trends: A compendium of data on global change. Carbon dioxide information analysis center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., USA 2007; on-line at http://cdiac.esd.ornl.gov/trends/emis/meth_reg.htm

[S33] British Petroleum. Statistical Review of World Energy 2007 2007; on-line at http://www.bp.com/productlanding.do?categoryId=6848&contentId=7033471

[S34] Intergovernmental Panel on Climate Change (IPCC), Climate Change 2001: Mitigation. Davidson O, Metz B, Eds. Cambridge Univ Press: New York, 2001; pp. 753.

[S35] World Energy Council, Survey of Energy Resources; http://www.worldenergy.org/publications/survey_of_energy_resources_2007/default.asp 2007

[S36] Keeling CD, Whorf TP. Trends: A Compendium on Global Change; Carbon Dioxide Information Analysis Center, Oak Ridge Nat. Lab., US. DOE: Oak Ridge, TN 2005.

[S37] Intergovernmental Panel on Climate Change (IPCC), Land Use, Land-Use Change, and Forestry. Watson RT, Noble IR, Bolin B, Ravindranath NH, Verardo DJ, Dokken DJ, Eds. Cambridge Univ Press: Cambridge, UK 2000; pp. 377.

[S38] Lüthi D, Le Floch M, Stocker TF, Bereiter B, Blunier T, Barnola J-M, Siegenthaler U, Raynaud D, Jouzel J. Unexpected low levels of CO_2 concentration between 650 and 750 kyr BP. Nature 2008; (in press).

[S39] Loulergue L, Schilt A, Spahni R, Masson-Delmotte V, Blunier T, Lemieux B, Barnola J-M, Raynaud D, Stocker TF, Chappellaz J. Orbital and millennial-scale features of atmospheric CH_4 over the last 800,000 years. Nature 2008; (in press).

[S40] Parrenin F, Dreyfus G, Durand G, *et al.* 1-D-ice flow modelling at EPICA Dome C and Dome Fuji, East Antarctica. Clim Past 2007; 3: 243-59.

[S41] Dreyfus G, Parrenin F, Lemieux-Dudon B, *et al.* Anomalous flow below 2700 m in the EPICA Dome C ice core detected using $\delta^{18}O$ of atmospheric oxygen measurements. Clim Past 2007; 3: 341-53.

[S42] Sempf M, Dethloff K, Handorf D, Kurgansky MV. Toward understanding the dynamical origin of atmospheric regime behavior in a baroclinic model. J Atmos Sci 2007; 64: 887-904.

[S43] Levitus S, Anatov JI, Boyer TP. Warming of the world ocean, 1955-2003. Geophys Res Lett 2005; 32: L02604; doi:10.1029/2004GL021592.

[S44] Frohlich C, Lean J. 1998; (http://www.pmodwrc.ch/pmod.php?topic=tsi/composite/SolarConstant)

[S45] Hansen J, Sato M, Ruedy R. Radiative forcing and climate response. J Geophys Res 1997; 102: 6831-64.

[S46] Shindell D, Schmidt GA, Miller RL, Rind D. Northern Hemisphere winter climate response to greenhouse gas, volcanic, ozone, and climate. J Geophys Res 2001; 106: 7193-210.

[S47] Johannessen OM, Bengtsson L, Miles MW, *et al* Arctic climate change: observed and modeled temperature and sea-ice variability. Tellus 2004; 56A: 328-41.

[S48] Dorn W, Dethloff K, Rinke A, Kurgansky M. The recent decline of the Arctic summer sea-ice cover in the context of internal climate variability. Open Atmos Sci 2008; 2: 91-100.

[S49] Dorn W, Dethloff K, Rinke A, Frickenhaus S, Gerdes R, Karcher M, Kauker F. Sensitivities and uncertainties in a coupled regional atmosphere-ocean-ice model with respect to the simulation of Arctic sea ice. J Geophys Res 2007; 112: D10118; doi:10.1029/2006JD007814.

[S50] Brand S, Dethloff K, Handorf D. Tropospheric circulation sensitivity to an interactive stratospheric ozone. Geophys Res Lett 2008; 35: L05809; doi:10.1029/2007GL032312.

[S51] Dethloff K, Rinke A, Benkel A, *et al*. A dynamical link between the Arctic and the global climate system. Geophys Res Lett 2006; 33: L03703; doi:10.1029/2005GL025245.

nature climate change

LETTERS

PUBLISHED ONLINE: 23 OCTOBER 2011 | DOI: 10.1038/NCLIMATE1258

Emission pathways consistent with a 2 °C global temperature limit

Joeri Rogelj[1]*, William Hare[2,3], Jason Lowe[4], Detlef P. van Vuuren[5,6], Keywan Riahi[7], Ben Matthews[8], Tatsuya Hanaoka[9], Kejun Jiang[10] and Malte Meinshausen[2,11]

In recent years, international climate policy has increasingly focused on limiting temperature rise, as opposed to achieving greenhouse-gas-concentration-related objectives. The agreements reached at the United Nations Framework Convention on Climate Change conference in Cancun in 2010 recognize that countries should take urgent action to limit the increase in global average temperature to less than 2 °C relative to pre-industrial levels[1]. If this is to be achieved, policymakers need robust information about the amounts of future greenhouse-gas emissions that are consistent with such temperature limits. This, in turn, requires an understanding of both the technical and economic implications of reducing emissions and the processes that link emissions to temperature. Here we consider both of these aspects by reanalysing a large set of published emission scenarios from integrated assessment models in a risk-based climate modelling framework. We find that in the set of scenarios with a 'likely' (greater than 66%) chance of staying below 2 °C, emissions peak between 2010 and 2020 and fall to a median level of 44 Gt of CO_2 equivalent in 2020 (compared with estimated median emissions across the scenario set of 48 Gt of CO_2 equivalent in 2010). Our analysis confirms that if the mechanisms needed to enable an early peak in global emissions followed by steep reductions are not put in place, there is a significant risk that the 2 °C target will not be achieved.

Cumulative emissions of long-lived greenhouse gases (GHGs) approximately define the temperature response of the climate system at timescales of centuries to millennia[2–4] because a significant fraction of CO_2 emissions, the dominant anthropogenic GHG, is removed very slowly from the atmosphere[5,6]. The temperature response will therefore continue, even when global emissions return to zero, or when concentrations are stabilized[6,7]. Cumulative emissions provide very little information on the technical feasibility and cost implications of following a particular 'emissions pathway', information that is needed for policymakers who are deciding now on emissions goals for the coming decades. Path-dependent assessments, such as the United Nations Environment Programme's *The Emissions Gap Report*[8], are therefore highly policy-relevant. This work extends the pathway analysis of that report (see Supplementary Information).

The Cancun Agreements refer to holding global mean temperature increase below 2 °C. Therefore, we do not allow a temperature overshoot in this study, although concentrations may temporarily overshoot a level that in equilibrium would lead to an exceedance of the temperature limit. There is increasing evidence from recent studies[7,9,10] that a decline of temperature might be unlikely on timescales relevant to human societies in the absence of strongly negative emissions. The slow ocean mixing that delays warming due to anthropogenic radiative forcing at present would also limit the amount of cooling for many decades to centuries[9–11].

Scenarios developed by integrated assessment models (IAMs) represent analyses of how society could evolve given assumed constraints of feasibility. In general, 'feasibility' encompasses technological, economic, political and social factors. IAMs account for some of these factors by assuming a set of mitigation technologies, constraining their potential and the rate at which these technologies can be introduced, amongst other things. Examples of such constraints include assumptions about the maximum feasible technology penetration rates, maximum cost, constraints on the use of renewables based on their intermittency and a maximum speed of specific system changes. Societal and political factors have typically received only limited attention: for instance, nearly all mitigation scenarios assume full participation of all regions in global mitigation efforts.

Scenarios from different IAMs consistent with different policy targets have been compared in previous studies[12,13]. Most of these focus on optimal (least-cost) pathways to achieve GHG concentration stabilization. Only recently, modelling comparison studies[12] have started focusing on second-best scenarios, which assume limited/delayed international participation of countries and/or reduced technology availability implying delayed emission reductions. The range in IAM outcomes for similar targets is broad, and reflects prevailing uncertainties captured by different methods and underlying assumptions[12,14,15]. Considering the combined impact on mitigation targets of both climate and technical and economic constraints and uncertainties has thus far received little attention.

Here we present a scenario reanalysis focusing on temperature targets. We use the carbon-cycle and climate model MAGICC6 (ref. 16), constrained by historical observations, to obtain estimates

[1]Institute for Atmospheric and Climate Science, ETH Zurich, Universitätstrasse 16, 8092 Zürich, Switzerland, [2]Potsdam Institute for Climate Impact Research (PIK), PO Box 60 12 03, 14412 Potsdam, Germany, [3]Climate Analytics GmbH, Telegrafenberg A26, 14412 Potsdam, Germany, [4]Met Office Hadley Centre, Department of Meteorology, University of Reading, Reading RG6 6BB, UK, [5]PBL Netherlands Environmental Assessment Agency, PO Box 303, 3720 AH Bilthoven, The Netherlands, [6]Utrecht Sustainability Institute, Utrecht University, Heidelberglaan 2, 3584 CS Utrecht, The Netherlands, [7]Energy Program, International Institute for Applied Systems Analysis (IIASA), Schlossplatz 1, A-2361 Laxenburg, Austria, [8]Georges Lemaître Centre for Earth & Climate Research, Université Catholique de Louvain, Place de l'Université 1, B-1348 Louvain-la-Neuve, Belgium, [9]National Institute for Environmental Studies, 16-2 Onogawa, Tsukuba, Ibaraki 305-8506, Japan, [10]Energy Research Institute, B1505, Jia. No. 11, Muxidibeili, Xichen Dist., Beijing 100038, China, [11]School of Earth Sciences, University of Melbourne, Victoria 3010, Australia. *e-mail: joeri.rogelj@env.ethz.ch.

© 2011 Macmillan Publishers Limited. All rights reserved.

Table 1 | Overview of pathway characteristics of emission pathways that limit global average temperature increase to below 2 °C relative to pre-industrial levels during the twenty-first century.

	Number of pathways	Peaking decade* (2000 + year)	Total GHG emissions in 2020 (Gt CO_2e)	Average industrial CO_2 post-peak reduction rates† (percentage of 2000 emissions per year)
'Very likely' chance (>90%) of staying below 2 °C during twenty-first century‡				
Without global net negative industrial CO_2 emissions	0	—	—	—
With global net negative industrial CO_2 emissions	3	10(—[10]—)15	41(—[43]—)44	3.2(—[3.3]—)3.3
All pathways	3	10(—[10]—)15	41(—[43]—)44	3.2(—[3.3]—)3.3
'Likely' chance (>66%) of staying below 2 °C during twenty-first century				
Without global net negative industrial CO_2 emissions	14	10(10[10]10)20	21(26[42]45)48	0(1.0[2.3]3.3)3.6
With global net negative industrial CO_2 emissions	12	10(10[10]15)15	41(41[44]46)48	1.5(1.7[3.0]3.5)3.8
All pathways	26	10(10[10]15)20	21(31[44]46)48	0(1.5[2.7]3.4)3.8
'At least fifty-fifty' chance (>50%) of staying below 2 °C during twenty-first century				
Without global net negative industrial CO_2 emissions	20	10(10[10]15)20	21(28[44]47)48	0(1.3[2.4]3.1)3.6
With global net negative industrial CO_2 emissions	19	10(10[10]20)30	41(42[45]48)50	1.2(1.7[3.0]3.6)5.9
All pathways	39	10(10[10]15)30	21(38[44]47)50	0(1.5[2.7]3.5)5.9

Data are provided for three probability options: a 'very likely' (greater than 90%), a 'likely' (greater than 66%) or 'at least fifty-fifty' (greater than 50%) chance.
Format: minimum(15%quantile[median]85%quantile)maximum. *The year given is an indication of the middle of the decade in which the peaking occurs in the scenarios. †Being relative to constant 2000 emissions, these reduction rates differ from exponential reduction rates (see Methods). ‡Owing to the low number of pathways, only minimum, median and maximum values are given for the 'very likely' option.

of future atmospheric GHG concentrations and transient temperatures (see Methods). This approach eliminates the uncertainty due to differing climate representations within the individual IAM studies[17]. We compiled a set of 193 emissions pathways from the literature (see Methods and Supplementary Information). Of this set, roughly one third represents baseline scenarios (that is, possible developments in the absence of climate policy intervention) and the remainder represents emission mitigation scenarios.

Owing to the uncertainty in our quantitative understanding of the climate system and carbon-cycle response to emissions, the projected results can be defined in terms of a probability of staying below a given temperature target. The choice of which target and with which probability it is to be reached can be informed by science but is fundamentally a political question depending on risk and value judgements. Policymakers in Cancun did not specify such a probability, neither quantitatively nor qualitatively. To cover a range of possible choices, we evaluate pathways for three options: a 'very likely' (greater than 90%), a 'likely' (greater than 66%) and an 'at least fifty-fifty' (greater than 50%) probability throughout the twenty-first century (see Methods). Pathways with a 'very likely' 2 °C probability are a subset of pathways with a 'likely' probability, which are in turn a subset of the pathways with an 'at least fifty-fifty' probability of limiting temperature increase to below 2 °C.

In our set, none of the baseline scenarios is able to limit the global temperature increase to below 2 °C. On the other hand, 3, 26 and 39 pathways have a 'very likely', 'likely' and 'at least fifty-fifty' chance to limit global temperature change to below 2 °C during the twenty-first century, respectively (Table 1, Fig. 1). In all pathways, emissions peak in the short term and decline later to stay below 2 °C. We start from estimated median 2010 emissions across our harmonized set (see Methods) of about 48 Gt of CO_2 equivalent (CO_2e). For pathways with a 'likely' chance of staying below 2 °C we find the following characteristics: median 2020 emissions are 44 Gt CO_2e, with a 15–85% quantile range of 31–46 Gt CO_2e. Most of these pathways (at least 85% of all cases) peak global emissions before 2020. After the peak, emissions decline. Still for the same pathways, median annual post-peak CO_2 reduction rates (see Methods) are around 2.7% (range 1.5–3.4%), and global total GHG emissions in 2050 show a median reduction of 45% (range 35–55%) below 1990 levels of 36.6 Gt CO_2e.

Besides a 2 °C limit, the Cancun Agreements furthermore include a commitment to review and consider strengthening the long-term goal, particularly in relation to a 1.5 °C limit. No ensemble member (including even the most stringent mitigation scenarios) limits warming to less than 1.5 °C throughout the entire century for any of the probability options. However, some scenarios in our set bring warming back below 1.5 °C by 2100: a first scenario (from 'POLES' in ref. 13) does so with a probability of about 50%, and a second scenario (from 'MERGE' in ref. 13) with a 'likely' chance (>66%).

An important difference[14] is noted between pathways that do not show global CO_2 emissions from energy and industry to become negative compared with those that do. Net negative emissions from the energy and industry sector may be possible through the application of a combination of capture and geological storage[18] of CO_2 (CCS) and bio-energy[19] (BECCS). In the pathways with no negative emissions, the median 2020 values for the 'likely' option are 2 Gt CO_2e lower at 42 Gt CO_2e (Table 1). Pathways that have net negative emissions (28 in total) feature higher rates of post-peak emission reductions while not exhibiting significant differences for the peak period. An in-depth analysis of the influence of BECCS on the

© 2011 Macmillan Publishers Limited. All rights reserved.

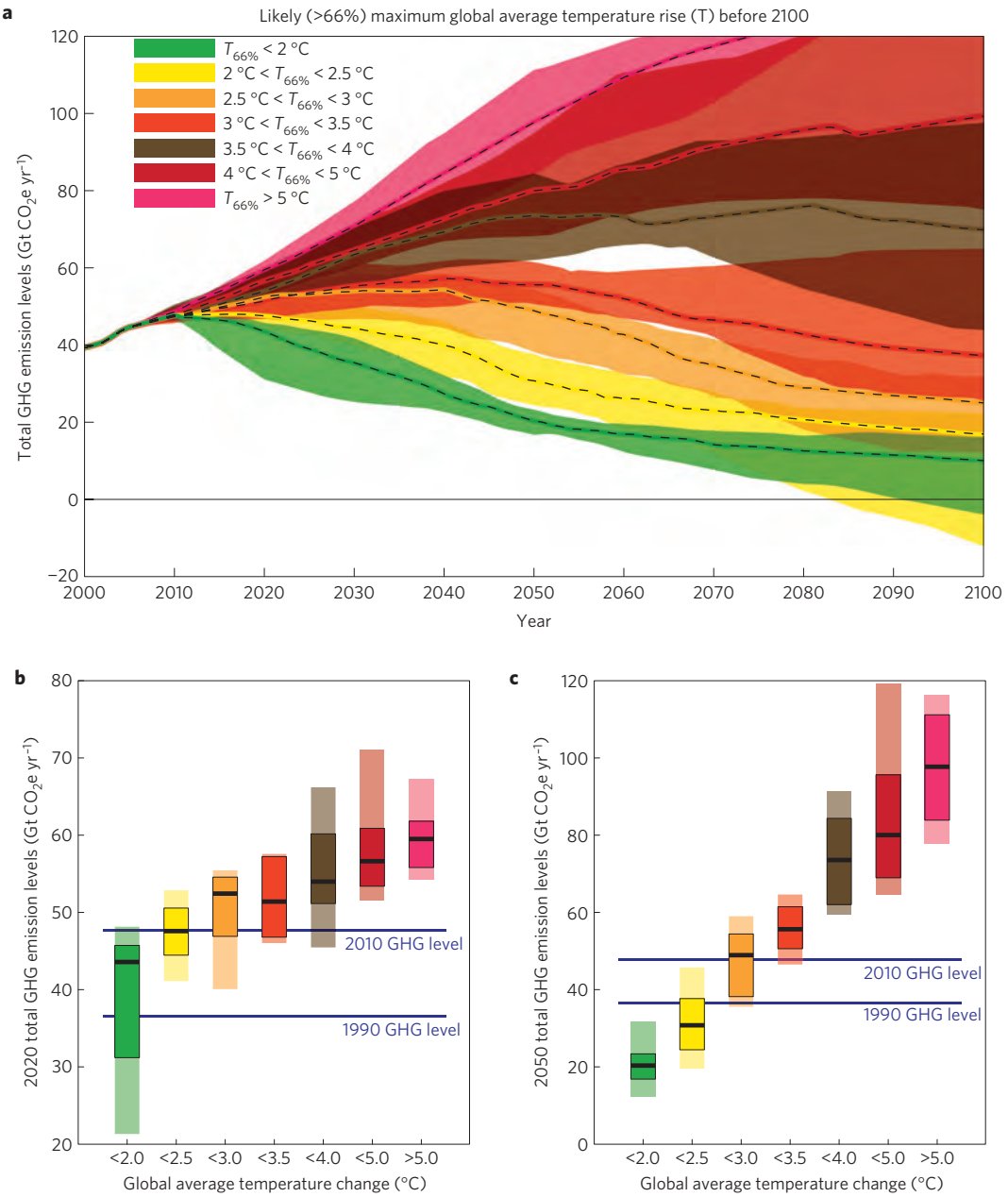


Figure 1 | Emission ranges of published IAM scenarios, colour coded as a function of the likely (greater than 66% probability) avoided global average temperature increase. a, 15–85% quantile ranges over time of global total GHG emissions of pathway sets consistent with a given temperature limit during the twenty-first century. Colour coding defines the respective temperature limit per pathway set. Black dashed lines show the median for each respective pathway set. **b**,**c**, 2020 (**b**) and 2050 (**c**) time slices of global total emissions consistent with a temperature limit during the twenty-first century. Shaded areas represent the minimum–maximum ranges; the coloured bounded rectangles the 15–85% quantile ranges and the thick black horizontal lines the median values for each temperature level, respectively. Horizontal blue lines represent median 1990 and 2010 emissions. Ranges for the other probability options (>90% and >50%) and time slices are given in Supplementary Figs S1–S5.

global peak of emissions is not possible with the available scenarios and would require specifically designed experiments that address this question.

Weakening the stringency of the 2 °C limit and accepting a lower chance of success (at least 50% instead of 66% probability), slightly shifts the 15–85% quantile range of scenarios in 2020 to 38–47 Gt CO_2e (the median remains at 44 Gt CO_2e). The peaking period remains during the present decade (precision-limited by the decadal-resolution data from the IAMs) and the median post-peak emission reduction rates are virtually the same as for the 'likely' case in more than 85% of the cases. Finally, the three pathways with a 'very likely' (greater than 90%) chance of success show a peak during this decade, 2020 emissions not exceeding 44 Gt CO_2e and post-peak reduction rates that are higher than the medians from the other cases. These three pathways have negative emissions.

Atmospheric CO_2 and CO_2e concentrations in 2100 of the pathways 'likely' consistent with 2 °C (Table 2) are around 425 ppm CO_2 (range 415–460) and 465 ppm CO_2e (range 435–475), respectively. Pathways consistent with 2 °C with a 'likely' or 'fifty-fifty' chance have peaked CO_2 concentrations during the twenty-first century (see Methods) in about 30 and 40% of the cases, respectively. CO_2-equivalent concentrations peaked in about 40% of the cases for both probability options. If scenarios do not peak concentrations, they stabilize during the twenty-first century. A

© 2011 Macmillan Publishers Limited. All rights reserved.

Table 2 | Overview of 2020 emissions, 2100 atmospheric CO_2 and total GHG concentrations of pathways that hold global average temperature increase below a specific temperature limit.

	Number of pathways	Total GHG emissions in 2020 (Gt CO_2e)	Atmospheric concentrations in 2100	
			CO_2 (ppm CO_2)	Total GHG (ppm CO_2e)
Emission pathways with a 'likely' (>66%) probability to limit temperature increase to below:				
1.5 °C	Insufficient data	Insufficient data	Insufficient data	Insufficient data
2 °C	26	21(31[44]46)48	375(412[423]457)468	400(436[463]476)486
2.5 °C	46	41(44[48]51)53	376(416[490]506)542	422(472[526]554)557
3 °C	45	40(47[52]55)55	477(501[542]574)616	554(561[609]636)645
3.5 °C	22	46(47[51]57)58	540(562[602]659)709	647(649[669]751)775
4 °C	18	45(51[54]60)66	649(661[726]811)890	759(782[833]869)939
5 °C	19	52(53[57]61)71	678(746[817]958)1104	851(922[993]1101)1134
Above 5 °C	10	54(56[59]62)67	888(905[975]1046)1049	1116(1153[1207]1318)1482

Data are provided for pathways that hold temperature increase to below a given temperature limit during the twenty-first century with a 'likely' (greater than 66%) chance. Results are given for temperature bins defined by the temperature limit and its preceding limit. For example, the '3 °C' row shows characteristics for emission pathways that limit warming below 3 °C with a 'likely' chance, but above 2.5 °C. See also Fig. 1 and Supplementary Fig. S6. Data for the other probability options are presented in Supplementary Figs S3, S5, S7 and S8, and in Supplementary Tables S1 and S2. Format: minimum(15%quantile[median]85%quantile)maximum.

decline afterward is not excluded. All 'very likely' chance pathways show a peak and decline in CO_2e concentrations of GHGs. More than 70% of the 'likely' chance scenarios assume global net negative CO_2 emissions from industry and energy to achieve such peaking. Furthermore, all scenarios that would comply with a 'fifty-fifty' chance and are outside the 'likely' subset include such negative emissions.

There are a number of caveats in interpreting our results. First, by describing the 15–85% quantiles over time, the intertemporal relationship between different emission paths is masked. Although the median path can be considered as a representative evolution of emissions for 'likely' pathways, the 15 and 85% quantile paths cannot. Emissions near the 85% quantile path in the first half of the century are followed by emissions near the 15% quantile path in the second half and vice versa (see Supplementary Fig. S9).

Second, besides results from the 15–85% quantiles, results outside this range also give insights. They provide information about potential future worlds in the tails of the distributions. A few pathways[20,21] (three in total) suggest that emissions could decline globally to about 30%–40% below 1990 levels by 2020. On the other side of the spectrum, one pathway[22] peaks at 48 Gt CO_2e in 2020 owing to delayed participation and still stays below 2 °C with a 'likely' chance. Another scenario[23] shows steep emission reduction rates of 5.9% after peaking at 50 Gt CO_2e around 2030, while still having an 'at least fifty-fifty' probability to stay below 2 °C. CCS contributes massively to the mitigation portfolio in this scenario, capturing up to almost double the present global CO_2 emissions per year by 2065. For most scenarios in our set, a peak in world emissions in 2030 would be more consistent with a 'likely' chance to stay below 3 °C instead of 2 °C.

A third issue is that for many scenarios the potential for net negative global CO_2 emissions from energy and industry is a crucial factor[14]. The potential of BECCS (refs 18,19) is already included in many IAMs. However, as for other advanced technologies, BECCS has not been demonstrated on a significant scale in the real world. Concerns exist with respect to CO_2 storage potential[18] as well as with respect to competition of large-scale bio-energy systems[24] with food production, biodiversity and ecosystem services. Other negative emission technologies, such as direct air capture of CO_2, are not explicitly included in most models at present.

Fourth, our set of pathways represents scenarios that are considered feasible by IAMs. The extent to which the realization of such scenarios is plausible in the real world goes beyond techno-economic and physical constraints represented by the IAMs, and also depends highly on factors such as political circumstances and public acceptance. Our analysis of the scenario space relies on the soundness and quality of the underlying IAM studies, and does not imply any independent assessment of the feasibility of the above-mentioned factors. We also acknowledge that only a limited set of scenarios were run for the low-temperature targets discussed here, and that scenario details are often not reported when IAMs find these targets infeasible[12]. Our findings, in particular with respect to low-emissions scenarios, therefore should be interpreted as an indication of the stringency of mitigation that would need to occur to keep specific targets within reach. They should, however, not be interpreted as a comprehensive assessment of the feasibility of the required mitigation action.

Related to this, it should be noted that most of the IAM scenarios used in this study tried to find cost-effective pathways for long-term climate targets. Scenarios that would look at economically less attractive[12,25] options could feature higher and/or later peaks with steeper declines afterwards. The ensemble we used was not designed to systematically sample all possible options, but represents an 'ensemble of opportunity'[26]. Clearly, IAMs do not set 'hard laws' on the consideration of whether achieving a particular scenario is possible. They are based on modellers' assumptions about technological and economic constraints, which are subject to change. Finally, a better understanding of socio-economic impacts of regional climate change and their inclusion in IAMs might have a large influence on the medium- and long-term cost efficiency of emission pathways. As understanding evolves, it will be necessary to update assessments such as the one presented here and develop studies that address this question directly. Furthermore, the treatment of political feasibility, including the will of national governments to implement transitions to low-carbon economies, remains a big unknown.

This analysis implies that the range of published IAM scenarios in line with the goal of staying below 2 °C with a 'likely' chance would peak during this decade and have annual 2020 emissions of around 44 Gt CO_2e (range of 31–46 Gt CO_2e). Our scenario set includes hardly any scenarios that take delayed participation of regions in international carbon markets into account. However, not assuming this at present seems optimistic given the reluctance of some major emitters to join such a system. Following higher 2020 emissions and later peaking as a result of weaker early mitigation action would significantly reduce the chances of staying below 2 °C. Without a firm commitment to put in place the mechanisms to enable an early global emissions peak followed by steep reductions thereafter, there are significant

© 2011 Macmillan Publishers Limited. All rights reserved.

risks that the 2 °C target, endorsed by so many nations, is already slipping out of reach.

Methods

We reanalysed an ensemble of 193 emission pathways from IAMs. This ensemble includes reference and mitigation pathways from model intercomparison studies (refs 12,13,27, among others, see Supplementary Table S3 for an overview of all references), as well as from other stabilization and non-intervention scenarios. All members are treated equally likely in the set.

Historical emission estimates come with a typical uncertainty range of 20–30% (ref. 28). Therefore, for each member of the ensemble, the historical emissions up to 2005 are harmonized to the historical multi-gas emission inventory developed in the framework of the representative concentration pathways[29,30] (RCPs). Emissions of each ensemble member are adjusted with a tapered scaling factor that returns to unity in 2050. This approach prevents possible amplification of negative emissions in the second half of the century[28]. When future emissions of a particular gas are missing, the multi-gas characteristics of the RCP3-PD scenario[31] are assumed, including sulphate aerosols, organic carbon, black carbon and atmospheric ozone precursors. The RCP3-PD scenario models strong environmental and climate policies. This choice is therefore consistent with our set-up to primarily analyse mitigation pathways that reduce emissions to be consistent with international temperature limits. Ozone-depleting substances controlled by the Montreal Protocol are assumed to follow a gradual phase-out during the twenty-first century.

After harmonization, six IAM pathways that show a decline or stabilization in historical emissions from 2005 to 2010 are excluded from the final ensemble. We also excluded one scenario for which insufficient detailed information about the underlying assumptions was available (as in ref. 12).

Each member of the harmonized multi-gas emission pathway ensemble is analysed probabilistically with the reduced-complexity climate system and carbon-cycle model MAGICC (ref. 16), version 6. MAGICC has been calibrated and shown to be able to reliably determine the atmospheric burden of CO_2 concentrations following high-complexity carbon-cycle models[16,32]. It is also able to project global average near-surface warming in line with estimates made by complex atmosphere–ocean general circulation models for a range of forcing scenarios, as assessed in the fourth assessment report (AR4) of the Intergovernmental Panel on Climate Change[33] (IPCC). Here it has been set up with historical constraints for observed hemispheric land/ocean temperatures and ocean heat-uptake (see Supplementary Information), emulating the C^4MIP carbon-cycle models[34] and with the same climate-sensitivity probability distribution as the 'illustrative default case' in ref. 2 that closely reflects IPCC estimates[33]. Herewith, the uncertainties in climate sensitivity, ocean heat-uptake and the response of the carbon-cycle to a given emissions pathway are taken into account. For each pathway, a 600-member ensemble is calculated to determine its resulting time-evolving temperature probability distribution.

We carried out a sensitivity analysis on the climate-sensitivity choice and on the assumptions regarding anthropogenic aerosols, soot and organic carbon, and found that our results are robust under those sensitivity cases (see Supplementary Information and Supplementary Table S4).

The range of results from this reanalysis of IAM pathways always refers to the median, and the 15–85% quantile range (as an approximation of the one-standard-deviation range around the mean). This provides a point of comparison with the approach in the IPCC AR4 (ref. 15). For completeness, also the minimum–maximum range is given. Total GHG emissions refer to emissions included in the Kyoto basket of GHGs, which contains carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride (SF_6) (see Supplementary Information). 'Negative CO_2 emissions' refer to net global emissions from energy and industry, excluding land-use emissions. The 'post-peak' reduction rates are calculated over the period between 10 and 30 years after the peak. To allow comparison and ensure consistency with the IPCC AR4, reduction rates are computed for global CO_2 emissions from energy and industry, and relative to 2000 levels. If fewer than 10 pathways were available in a particular subset, only median, minimum and maximum values are provided. If a pathway yields atmospheric CO_2 concentrations in 2100 that are at least 5% lower than the maximum concentration during the twenty-first century, this pathway is defined to have peaked concentrations during this century. The same approach applies to the total GHG (CO_2e) concentrations.

Temperatures projections 'relative to pre-industrial' are calculated relative to the 1850–1875 base period.

Received 16 June 2011; accepted 22 September 2011; published online 23 October 2011

References

1. United Nations Framework Convention on Climate Change *Report of the Conference of the Parties on its Sixteenth Session, held in Cancun from 29 November to 10 December* 2010 (FCCC/CP/2010/7/Add.1, United Nations, 2011); available at http://unfcc.int/resource/docs/2010/cop16/eng/07a01.pdf.
2. Meinshausen, M. *et al.* Greenhouse-gas emission targets for limiting global warming to 2 °C. *Nature* **458,** 1158–1162 (2009).
3. Matthews, H. D., Gillett, N. P., Stott, P. A. & Zickfeld, K. The proportionality of global warming to cumulative carbon emissions. *Nature* **459,** 829–832 (2009).
4. Allen, M. R. *et al.* Warming caused by cumulative carbon emissions towards the trillionth tonne. *Nature* **458,** 1163–1166 (2009).
5. Archer, D. *et al.* Atmospheric lifetime of fossil fuel carbon dioxide. *Annu. Rev. Earth Planet. Sci.* **37,** 117–134 (2009).
6. Plattner, G. K. *et al.* Long-term climate commitments projected with climate & carbon cycle models. *J. Clim.* **21,** 2721–2751 (2008).
7. Lowe, J. A. *et al.* How difficult is it to recover from dangerous levels of global warming? *Environ. Res. Lett.* **4,** 014012 (2009).
8. United Nations Environment Programme *The Emissions Gap Report — Are the Copenhagen Accord Pledges Sufficient to Limit Global Warming to 2 °C or 1.5 °C*? (UNEP, 2010).
9. Held, I. M. *et al.* Probing the fast and slow components of global warming by returning abruptly to preindustrial forcing. *J. Clim.* **23,** 2418–2427 (2010).
10. Solomon, S. *et al.* Persistence of climate changes due to a range of greenhouse gases. *Proc. Natl Acad. Sci. USA* **107,** 18354–18359 (2010).
11. Schewe, J., Levermann, A. & Meinshausen, M. Climate change under a scenario near 1.5 °C of global warming: Monsoon intensification, ocean warming and steric sea level rise. *Earth Syst. Dynam.* **2,** 25–35 (2011).
12. Clarke, L. *et al.* International climate policy architectures: Overview of the EMF 22 International Scenarios. *Energy Econ.* **31,** S64–S81 (2009).
13. Edenhofer, O. *et al.* The economics of low stabilization: Model comparison of mitigation strategies and costs. *Energy J.* **31,** 11–48 (2010).
14. van Vuuren, D. & Riahi, K. The relationship between short-term emissions and long-term concentration targets. *Climatic Change* **104,** 793–801 (2011).
15. IPCC *Climate Change 2007: Mitigation of Climate Change* (eds Metz, B., Davidson, O. R., Bosch, P. R., Dave, R., & Meyer, L. A.) (Cambridge Univ. Press, 2007).
16. Meinshausen, M., Raper, S. C. B. & Wigley, T. M. L. Emulating coupled atmosphere-ocean and carbon cycle models with a simpler model, MAGICC6 — Part 1: Model description and calibration. *Atmos. Chem. Phys.* **11,** 1417–1456 (2011).
17. van Vuuren, D. *et al.* How well do integrated assessment models simulate climate change? *Climatic Change* **104,** 255–285 (2011).
18. IPCC *Special Report on Carbon Dioxide Capture and Storage* (eds Metz, B., Davidson, O., de Coninck, H., Loos, M. & Meyer, L.) (Cambridge Univ. Press, 2005).
19. Azar, C. *et al.* The feasibility of low CO_2 concentration targets and the role of bio-energy with carbon capture and storage (BECCS). *Climatic Change* **100,** 195–202 (2010).
20. Barker, T. & Scrieciu, S. Modeling low climate stabilization with E3MG: Towards a 'new economics' approach to simulating energy–environment–economy system dynamics. *Energy J.* **31,** 137–164 (2010).
21. Loulou, R., Labriet, M. & Kanudia, A. Deterministic and stochastic analysis of alternative climate targets under differentiated cooperation regimes. *Energy Econ.* **31,** S131–S143 (2009).
22. Krey, V. & Riahi, K. Implications of delayed participation and technology failure for the feasibility, costs, and likelihood of staying below temperature targets—Greenhouse gas mitigation scenarios for the 21st century. *Energy Econ.* **31,** S94–S106 (2009).
23. Calvin, K. *et al.* 2.6: Limiting climate change to 450 ppm CO_2 equivalent in the 21st century. *Energy Econ.* **31,** S107–S120 (2009).
24. Wise, M. A. *et al.* Implications of limiting CO_2 concentrations for land use and energy. *Science* **324,** 1183–1186 (2009).
25. O'Neill, B. C., Riahi, K. & Keppo, I. Mitigation implications of midcentury targets that preserve long-term climate policy options. *Proc. Natl Acad. Sci. USA* **107,** 1011–1016 (2009).
26. Tebaldi, C. & Knutti, R. The use of the multi-model ensemble in probabilistic climate projections. *Phil. Trans. R. Soc. A* **365,** 2053–2075 (2007).
27. Luderer, G. *et al.* The economics of decarbonizing the energy system—results and insights from the RECIPE model intercomparison. *Climatic Change* http://dx.doi.org/10.1007/s10584-011-0105-x (2011).
28. Rogelj, J., Hare, W., Chen, C. & Meinshausen, M. Discrepancies in historical emissions point to a wider 2020 gap between 2 °C benchmarks and aggregated national mitigation pledges. *Environ. Res. Lett.* **6,** 1–9 (2011).
29. Meinshausen, M. *et al.* The RCP greenhouse gas concentrations and their extensions from 1765 to 2300. *Climatic Change* http://dx.doi.org/10.1007/s10584-011-0156-z (2011).
30. Granier, C. *et al.* Evolution of anthropogenic and biomass burning emissions of air pollutants at global and regional scales during the 1980–2010 period. *Climatic Change* http://dx.doi.org/10.1007/s10584-011-0154-1 (2011).
31. van Vuuren, D. *et al.* RCP2.6: Exploring the possibility to keep global mean temperature increase below 2 °C. *Climatic Change* http://dx.doi.org/10.1007/s10584-011-0152-3 (2011).

© 2011 Macmillan Publishers Limited. All rights reserved.

32. Meinshausen, M., Wigley, T. M. L. & Raper, S. C. B. Emulating atmosphere–ocean and carbon cycle models with a simpler model, MAGICC6 — Part 2: Applications. *Atmos. Chem. Phys.* **11,** 1457–1471 (2011).
33. IPCC *Climate Change 2007: The Physical Science Basis (eds Solomon, S. et al.)* (Cambridge Univ. Press, 2007).
34. Friedlingstein, P. *et al.* Climate–carbon cycle feedback analysis: Results from the C4MIP model intercomparison. *J. Clim.* **19,** 3337–3353 (2006).

Acknowledgements

The authors gratefully thank everyone involved in the UNEP *Emissions Gap Report*, and acknowledge the contributions of all modelling groups that provided data and information, all co-authors from the UNEP *Emissions Gap Report* and others who provided comments, in particular B. Knopf, G. Luderer, E. Sawin, B. O'Neill, B. Ward, N. Ranger, V. Bossetti and R. Knutti. J.R. was supported by the Swiss National Science Foundation (project 200021-135067). J.L. was supported by the Joint DECC/Defra Met Office Hadley Centre Climate Programme (GA01101) and the AVOID programme (GA0215).

Author contributions

J.R., W.H., J.L., K.R., B.M., M.M. and D.P.v.V. designed the research. M.M. developed the climate model set-up. J.R. carried out the research. All authors discussed the results and contributed to writing the paper.

Additional information

The authors declare no competing financial interests. Supplementary information accompanies this paper on www.nature.com/natureclimatechange. Reprints and permissions information is available online at http://www.nature.com/reprints. Correspondence and requests for materials should be addressed to J.R.

© 2011 Macmillan Publishers Limited. All rights reserved.

WWF for a living planet®

ECOFYS

Sharing the effort under a global carbon budget

OUR MISSION: A SUSTAINABLE ENERGY SUPPLY FOR EVERYONE

ECOFYS

Ecofys Germany GmbH
Am Wassermann 36
50829 Köln
Germany

W: www.ecofys.de
T: +49 (0) 221 270 70 100
F: +49 (0) 221 270 70 011
E: info@ecofys.de

Sharing the effort under a global carbon budget

Niklas Höhne
Sara Moltmann

24 August 2009

Commissioned by:
WWF International

PECSDE082855
PECPDE083519

WWF foreword

In order to avoid dangerous climate change there is a growing consensus among now more than 120 countries that average global temperatures should not increase by more than 2°C over pre-industrial levels. This was affirmed in July of this year by the G8+5 nations, a group of countries encompassing all major emitters from the developed and developing world. This is a giant leap forward and provides large hope for success of the ongoing negotiations for a post-2012 treaty to be agreed in Copenhagen at the Climate Summit in December this year.

How can this objective be met? WWF and other members of the Climate Action Network (CAN) are strongly promoting a legally binding mid-term target of at least 40% emissions reductions by 2020 below 1990 levels for developed countries as a group, under common but differentiated responsibilities that require nations that are rich and have high per capita emissions to 'pay back' their atmospheric debt. Globally, all countries need to have reduced their total greenhouse gas emissions by at least 80% below 1990 levels by 2050 in order for the world to stay below 2°C of warming.

The emissions trajectory between now and 2050 needs to be distributed in an equitable way with the appropriate distinctions made between 'rich' and 'poor' and between 'high' and 'low' per capita emitters. To inform the international debate, WWF asked the leading energy research consultancy ECOFYS to elaborate on the practicalities and implications of some suggested methodologies already under discussion and some that are promising and should receive consideration.

As well as the need for an 80% cut in emissions globally by 2050, another requirement taken into account by the research was the need to cut global emissions by 30% over 1990 levels by 2030 – a feasible as well as necessary target according to a recent climate action cost calculation, the McKinsey Climate Cost Curve 2.0. Also, land use factors globally need to turn from being a net source of CO_2 to becoming a net sink between 2020 and 2030, with major reductions required in emissions from deforestation and clearing in the tropics. Action at this level could ensure the entire world becomes a net emissions sink post 2060.

Although WWF has strong sympathy with the Greenhouse Gas Development Right Framework to distribute the allowable emissions in a social and equitable way in the next decades, at this point in time WWF is not promoting any particular approach to distribute the finite global greenhouse gas budget between 1990 and 2100. But whichever approach the world chooses in order to stay below 2°C, the cumulative greenhouse gas budget cannot change substantially. If we relax on the trajectory of one country, another country needs to pick up the bill. There is no carbon offset for Planet Earth as such. We know, decarbonising the economy in the next 50 years or so will be tough for most nations – and let us be very honest – particularly for many rapidly industrialising nations.

However, unabated climate change will cost much more socially, economically and environmentally. It will wreak havoc on global food security and freshwater availability, and its impacts will be disproportionately felt by poor and vulnerable communities. What WWF seeks to do with this paper is to kick-start a debate on how to globally share the carbon budget consistent with a trajectory to keep global warming below 2°C. This is not about burden sharing – this is about benefit sharing. Compared to unabated climate change, perceived economic 'hardship' is a luxury problem.

Stephan Singer
Director, Global Energy Policy
WWF International

Kim Carstensen
Leader, Global Climate Initiative
WWF International

Executive summary

Stringent global greenhouse gas emission reductions by all sectors and all countries will be necessary to keep global average temperature increase below 2°C. This report gives an overview of different methods to share the effort of reducing greenhouse gas emissions between countries to reach a given global carbon budget by 2100 in line with the 2°C limit.

First, we defined the carbon budget, which is the amount of tolerable global emissions over a period of time. Afterwards, we divided the available emission rights among countries according to different rules. To be consistent with the 2°C limit, for this report we assume CO_2eq emissions will have to be reduced by 30% compared to 1990 levels by 2030. By 2050 global emissions excluding those from land-use change and forestry (LUCF) need to be reduced by 80% compared to 1990. This leads to an emission budget of roughly 1800 GtCO_2eq between 1990 and 2100 excluding LUCF. Further, we assume that emissions from LUCF remain constant at about 4 GtCO_2 until 2010 and decline to zero by between 2010 and 2020. LUCF will become a stable net sink of emissions afterwards. By 2030 LUCF will remain at -4 GtCO_2. The global emission budget including LUCF will, thus, be about 1600 GtCO_2eq. This is the budget between 1990 and 2100. Until today and because mankind has already increased its global emissions substantively since 1990, the remaining net cumulative budget between 2009 and 2100 is limited to 870 GtCO2eq. This translates to an allowable global annual emission on average for the next 91 years of no more than 9.5 GtCO_2eq, or about 20% of today's annual net global emissions.

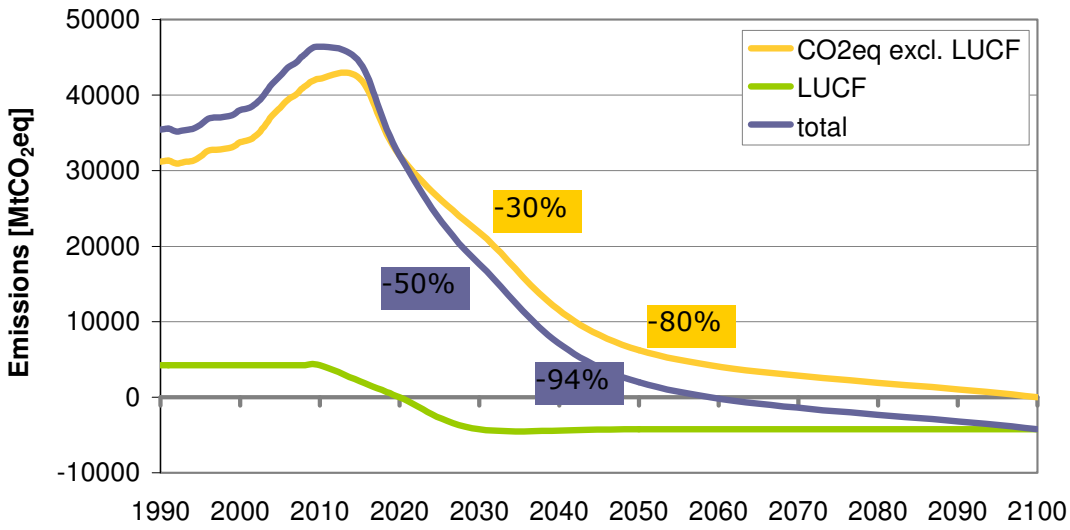


Figure 1. Possible global GHG emissions pathway between 1990 and 2100 according to a global carbon budget of about 1800 Mt CO_2eq (excl. LUCF) and 1600 Mt CO_2eq (incl. LUCF)

Under this strict emission budget, delay in reductions of only 5 years has significant consequences. Starting absolute global emission reductions around the year 2015 requires global average annual emissions reductions of about 5%, which already is very ambitious. Starting absolute global reduction in 2020 requires a global annual reduction of 8% after 2020.

The requirements to reach this are very stringent (see Figure 2). This is also reflected by the resulting target of about 0.5 tCO_2eq per capita as global average in 2050. In

2020 the average per capita emissions are around 9 tCO_2eq per capita for Annex I and 3-5 tCO_2eq per capita for non-Annex I.

We have shared the global emission budget using three methodologies, which are currently under discussion:

- Greenhouse Development Rights (GDRs): All countries need to reduce emissions below their business as usual path based on their responsibility (cumulative emissions) and capacity (GDP). Only emissions and GDP of the population above a development threshold account towards responsibility and capability.
- Contraction and Convergence (C&C): The targets for individual countries are set in such a way that per capita emission allowances converge from the countries' current levels to a level equal for all countries within a given period, here until 2050.
- Common but Differentiated Convergence (CDC): As above, targets are set so per capita emissions for all countries converge to an equal level over the period 2010 to 2050. For developed (Kyoto Protocol Annex I) countries' per capita emission allowances convergence starts immediately. For individual non-Annex I countries' per capita emissions convergence starts from the date when their per capita emissions reach a certain percentage threshold of the (gradually declining) global average.

Generally, the Greenhouse Development Rights approach (GDRs) allows negative emissions where required reductions based on capacity and responsibility are larger than business as usual emissions. Contraction and Convergence (C&C) and Common But Differentiated Convergence (CDC) allow only very low but not negative emission levels. Therefore, Annex I emission targets go to -60% in 2020 under the GDRs, while the other approaches require around -40%.

Negative emission allowances (below 100% of base year) do not mean that the respective countries have to mitigate everything domestically. This is just a method of illustrating the equitable emissions allocations under this methodology. In reality it means that industrialised countries have to substantially support reducing emissions in developing countries via the carbon market, technology and/or funding etc.

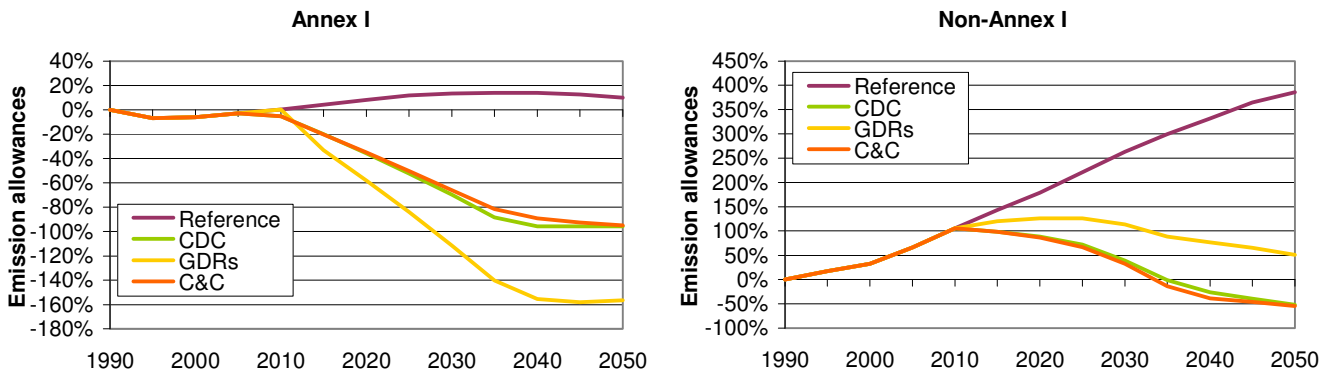


Figure 2. Development of emission allowances for Annex I countries and Non-Annex I countries between 1990 (0%) and 2050 under the effort sharing approaches CDC, GDRs and C&C

Developing countries in general and economies in transition (EITs) have more room to grow under GDRs than under the other approaches. The main reasons for this are the relatively low per capita emissions combined with limited financial capacity.

Least Developed Countries (LDCs) are almost all exempt from emission reduction requirements under GDRs, while under C&C they are granted little more allowances than their reference emissions until 2020 and face reduction obligations after 2025. Under CDC they face reductions after 2030.

Cumulative emissions per capita vary considerably under C&C and CDC for Annex I and non-Annex I. For GDRs some non-Annex I countries are even granted higher per capita cumulative emissions than some countries of Annex I.

Under GDRs, non-Annex I countries are allowed to increase their total emissions and peak until 2025 and then need to reduce them to roughly today's level in 2050 (about 50% above 1990). Under C&C and CDC there is less room for growth and their emissions need to be at a third of today's emissions (half of 1990's emissions). This is particularly reflected in the case of China and India. Both countries would be entitled under GDR to grow their emissions by 10% and even 240%, respectively, by 2050 compared to 1990, while being required to reduce by more than 70% and about 2-7% in the same period under the other two models.

Table of contents

1 Introduction 10
2 Global carbon budget 11
3 Global effort sharing 13
3.1 Parameters 13
3.1.1 Greenhouse development rights (GDRs) 13
3.1.2 Contraction and convergence (C&C) 14
3.1.3 Common but differentiated convergence (CDC) 15
3.1.4 Overview of all considered effort-sharing approaches 17
3.2 Results 18
4 Conclusions 26
References 27
Appendix A Description of the EVOC tool 28
Appendix B Emission allowances distributed with EVOC 33
Appendix C Comparison of data from EcoEquity and EVOC 39

List of Abbreviations

BAU	Business as usual
C	Capacity
C&C	Contraction and Convergence
CDC	Common but differentiated convergence
CDM	Clean development mechanism
CO_2eq	Carbon dioxide equivalents
EIT	Economies in transition
GDP	Gross domestic product
GDRs	Greenhouse Development Rights
LDC	Least developed country
LUCF	Land-use change and forestry
R	Responsibility
RCI	Responsibility Capacity Index
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States dollar

1 Introduction

Further action is needed that goes far beyond what has been agreed so far under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol to "prevent dangerous anthropogenic interference with the climate system", the ultimate objective of the UNFCCC. It is beyond question that developed countries (Annex I countries) will have to take a leading role. They will have to commit to substantial emission reductions and financing commitments due to their historical responsibility and their financial capability. However, the stabilisation of the climate system will require global emissions to peak within the next decade and decline well below current levels by the middle of the century. It is hence a global issue and, thus, depends on the participation of as many countries as possible.

More than 120 countries, including the European Community and many developing nations particularly LDC and Small Island Nations, and numerous development, social justice and environmental NGOs have agreed that global average temperature increase should be limited to 2°C above pre-industrial levels to avoid such dangerous interference. Recent proposals, e.g. of the Alliance of Small Island States, now call for 1.5°C. The risk that a stable greenhouse gas concentration of e.g. 450 ppmv CO_2eq would result in global average temperature above 2°C in the long term is around 50%. At 400 ppmv CO_2eq, the risk is 30% (Meinshausen 2005). Consequently, global emissions have to peak in the next 15 years and decline well below the 1990 level in 2050 and further thereafter.

Under the principle of "common but differentiated responsibilities", one of the guiding principles stipulated in Article 3.1 of the UNFCCC, developed countries (so called Annex I Parties) take the lead in reducing emissions and developing countries (Non-Annex I Parties) act to protect the climate system on the basis of equity and in accordance with the common but differentiated responsibilities and respective capabilities. Current international climate negotiations center around "mitigation commitments and actions" for developed countries and "nationally appropriate mitigation actions" for developing countries.

Developing countries have a lower historical responsibility for climate change but some are already or will become important emitters. A less carbon intensive development path will have positive effects on these countries' sustainable development and on the global climate system. On the one hand, climate change action will contribute directly to achieving sustainable development objectives, such as energy security, sustainable economic development, technology innovation, job creation, local environmental protection and enhancement of capacity to adapt to climate change impacts. On the other hand, especially developing countries will benefit from a more stable global climate because they are the most vulnerable to climate change effects.

In this report for WWF International Ecofys analyses emission allowances for different groups of countries until 2050 under a given carbon budget between 1990 and 2100. The analysed approaches consider all countries but give different weight to Annex I and non-Annex I efforts.

We first describe the carbon budget and the methodology used (Chapter 2), then we briefly describe the considered effort sharing approaches (Chapter 3). Afterwards, we present the results as emission allowances per group under the different effort sharing approaches (Chapter 3.2). Finally, we give a short conclusion of this analysis. Detailed data and a description of the used calculation model (EVOC) are included in the Appendix.

2 Global carbon budget

Different approaches exist for global effort sharing of greenhouse gas emission reductions. One possibility is to define the carbon budget, which is the global amount of tolerable emissions over a period of time. Afterwards the available emission rights can be divided among countries according to different rules. To come close to 2° limit, for this report we assume CO_2eq emissions will have to be reduced by 30% compared to 1990 levels by 2030. By 2050 global emissions excluding LUCF need to be reduced by 80% compared to 1990. This leads to an emission budget of roughly 1800 Gt CO_2eq between 1990 and 2100.

As emissions from land use change and forestry (LUCF) are known only with considerable uncertainty, we took simplifying assumptions about current and future emissions from this sector. We assume that emissions from land-use change and forestry (LUCF) remain constant at about 4 $GtCO_2$ until 2010 and decline to zero by between 2010 and 2020. Due to reducing deforestation and increasing re- and afforestation LUCF will have to become a net sink of emissions afterwards (see Figure 3 and Table 1 below). We assume that after 2030 LUCF will remain at -4 $GtCO_2$. The global emission budget including LUCF will, thus, be about 1600 $GtCO_2$eq between 1990 and 2100.

Because mankind has already increased its global emissions substantively since 1990, the remaining net cumulative budget between 2009 and 2100 is limited to 870 $GtCO_2$eq. This translates to an allowable global annual emission on average for the next 91 years of no more than 9.5 $GtCO_2$eq, or about 20% of today's annual net global emissions.

In order to stay within the boundary of the global GHG budget, sometime from 2060 onwards, net global emissions must be negative (little emissions from energy use and larger sequestration of carbon from forests and other technologies).

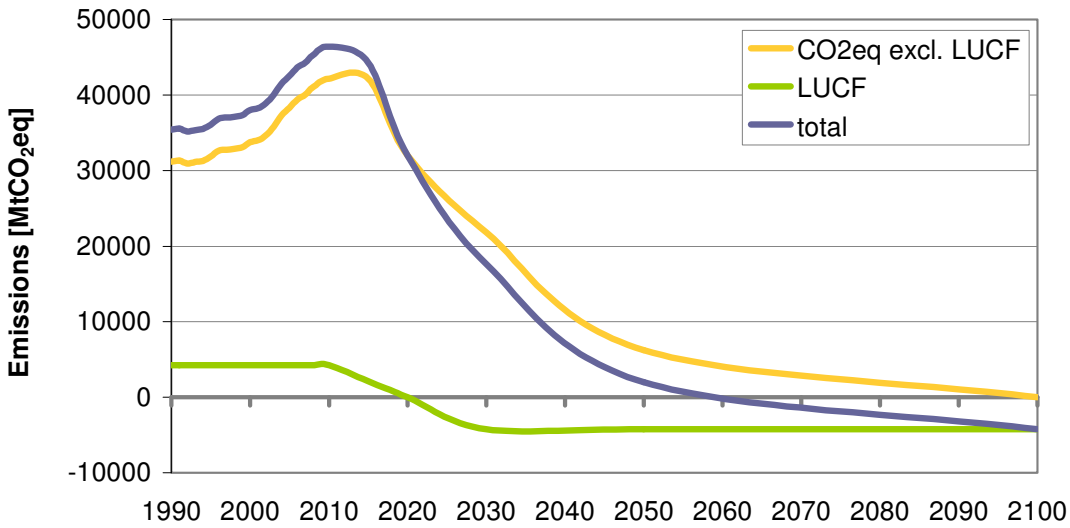


Figure 3. Possible global GHG emissions pathway between 1990 and 2100 according to a global carbon budget of about 1800 Mt CO_2eq (excl. LUCF) and 1600 Mt CO_2eq (incl. LUCF)

Table 1. Assumption on cumulative GHG emissions between 1990 and 2100

	2030 emissions [% change from 1990]	2050 emissions [% change from 1990]	Cumulative emissions				
			1990-2008	2009-2100	1990-2050	2010-2050	1990-2100
CO_2eq excl. LUCF	-30%	-80%	650	1160	1660	970	1820
LUCF	-200%	-200%	80	-290	0	-80	-210
Total emissions	**-50%**	**-94%**	**730**	**870**	**1660**	**880**	**1600**

Generally, one can imagine different pathways to reduce emissions that satisfy the same budget. Figure 4 gives an example of three different emission paths. The yellow path requires absolute global emission reduction comparatively early around the year 2015. The required average annual emissions reduction is about 5%. The medium path (dark violet) starts absolute emission reduction about 2-3 years later. The annual reduction rate is similar about 6%. The third path (light violet) requires absolute global reduction in 2020. As a result also the annual reduction of 8% after 2020 is more challenging to achieve a global carbon budget that is comparable with the yellow path of early reduction.

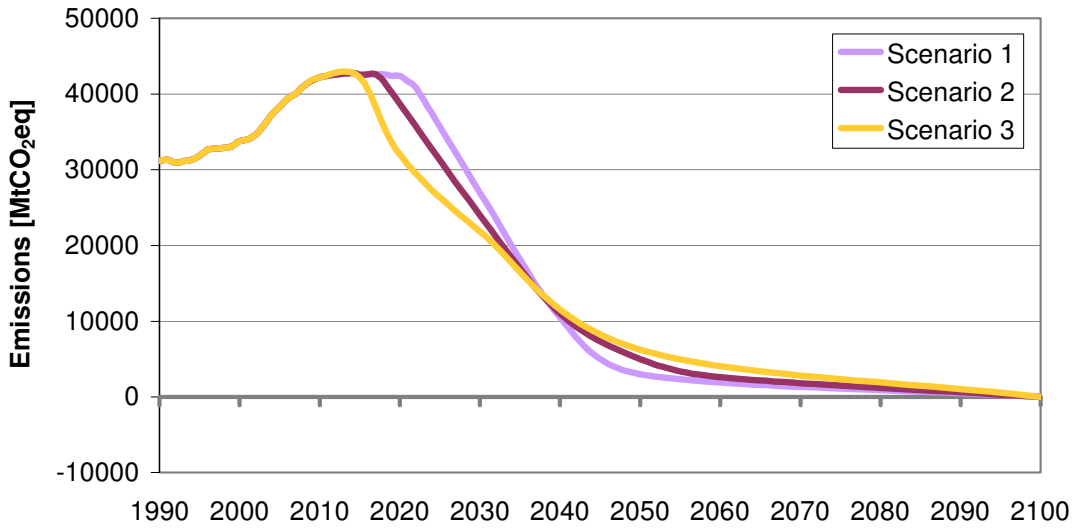


Figure 4. Sensitivity of possible global GHG emissions pathway excl. LUCF between 1990 and 2100

Table 2. Cumulative GHG emissions excl. LUCF between 1990 and 2100

Scenario	2030 emissions [% change from 1990]	2050 emissions [% change from 1990]	Cumulative emissions 1990-2050	Cumulative emissions 1990-2100
Scenario 1	-13%	-80%	~1750	~1830
Scenario 2	-30%	-80%	~1670	~1830
Scenario 3	-23%	-84%	~1700	~1830

3 Global effort sharing

3.1 Parameters

This section presents the parameters applied for three possible future methodological architectures consistent with the considered global carbon budget. This means that the calculation outcomes have to meet the global reference emissions of -30% compared to 1990 levels in 2030 and -80% in 2050 mentioned above. The following approaches are included in the calculation of emission allowances:

- Greenhouse Development Rights
- Common but Differentiated Convergence
- Contraction and Convergence by 2050

For this comparison of the emission rights under different distribution approaches in a future architecture the Evolution of Commitments tool (EVOC) is used. A detailed description of the EVOC model is included in Appendix A.

3.1.1 Greenhouse development rights (GDRs)

The Greenhouse Development Rights (GDRs) approach to share the effort of global greenhouse gas emissions reduction was developed by Baer et al. (Baer et al. 2007, 2008; cp. also Niklas Höhne and Sara Moltmann 2008). It is based on three main pillars:

The right to develop: Baer et al. assume the right to develop as the essential part for any future global climate regime in order to be successful. Therefore a development threshold is defined. Below this level individuals must be allowed to make development their first priority and do not need to contribute to the global effort of emission reduction or adaptation to climate change impacts. Those above this threshold will have to contribute regardless their nationality. This means that individuals above this threshold will have to contribute even if they live in a country that has an average per capita income below this level. The level for this development threshold would have to be matter of international debate. However Baer et al. 2008 suggest an income-level of $7,500 per capita and year. Based on this, the effort sharing of the GDRs is based on the capacity and the responsibility of each country.

Capacity: The capacity (C) of a county is reflected by its income. The income distribution among individuals is taken into account by the gini coefficient of a country. A gini coefficient close to 1 indicates low equality while a value close to 0 indicates a high equality in income distribution. As the countries capacity is needed to define per-country emission allowances the sum of income of those individuals per country above the development threshold is summed and considered to calculate each countries capacity.

Responsibility: The responsibility (R) is based on the "polluter pays" principle. For the GDRs according to Baer et al. it is measured as cumulative per capita CO_2 emissions from fossil fuel consumption since 1990. However, it should be distinguished between survival emissions and luxury emissions. Baer et al. assume that emissions are proportional to consumption, which again is linked to income. Emissions related to that share of income below the development threshold are equivalent to the part of national income that is not considered in calculating a countries capacity. Therefore, they shall be considered as survival emissions. Those emissions linked to income above the development threshold are luxury emissions and shall account for a countries responsibility.

Allocation of emission rights: The allocation of emission reduction obligations and resulting emission rights is based on each country's responsibility and capacity, combined in the Responsibility Capacity Index (RCI). This is defined as $RCI = R^a \cdot C^b$, where *a* and *b* are weighting factors. Baer et al. assume and equal weighting of 0.5 for *a* and 0.5 for *b*. This gives capacity and responsibility an equal weighting.

Two global emissions development paths are considered. First, the business-as-usual (BAU) case and second the reduction path necessary to reach the emission level in order to stabilise global emissions (see Figure 5). The difference of these two is the amount of emissions that need to be reduced globally. Each country's annual share of this reduction is determined by the relative share of its RCI compared to the sum of RCIs of all other countries.

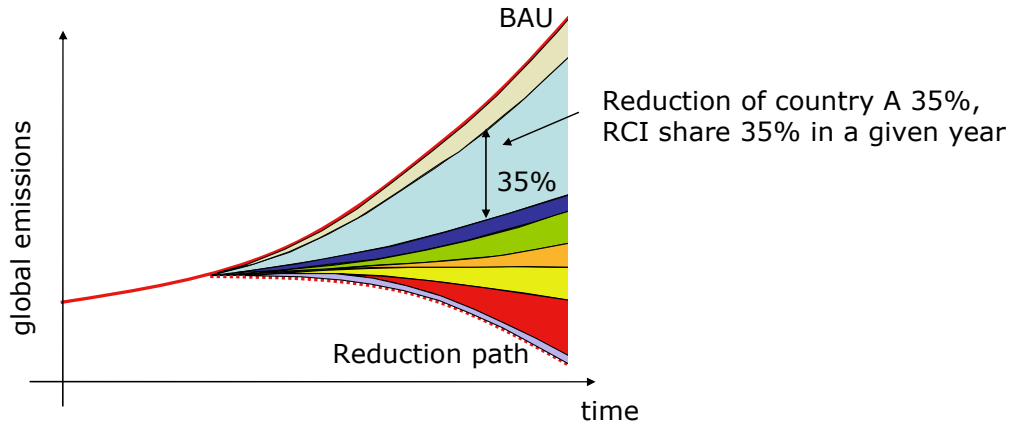


Figure 5. Effort sharing under the Greenhouse Development Rights (GDRs) approach according to the Responsibility Capacity Index (RCI)

Table 3 includes the parameters chosen for the calculations on the GDRs approach in this report.

Table 3. Parameters chosen for the Greenhouse Development Rights approach

Parameter	Unit	
Development threshold	USD (2005) / capita / year	7,500
Start year for cumulative emissions		1990
Weighting of Capacity	%	50%
Weighting of Responsibility	%	50%

3.1.2 Contraction and convergence (C&C)

Under contraction and convergence (C&C) (GCI 2005; Meyer 2000), all countries participate in the regime with quantified emission targets. As a first step, all countries agree on a path of future global emissions that leads to an agreed long-term stabilisation level for greenhouse gas concentrations ('contraction'). As a second step, the targets for individual countries are set in such a way that per capita emission allowances converge from the countries' current levels to a level equal for all countries within a given period ('convergence'). The convergence level is calculated at a level that resulting global emissions follow the agreed global emission path. It might be more difficult for some countries to reduce emissions compared to others, e.g. due to

climatic conditions or resource availability. Therefore, emission trading could be allowed to level off differences between allowances and actual emissions. However, C&C does not explicitly provide for emission trading.

As current per capita emissions differ greatly between countries some developing countries with very low per capita emissions, (e.g. India, Indonesia or the Philippines) could be allocated more emission allowances than necessary to cover their emissions (some call this "tropical hot air"). This would generate a flow of resources from developed to developing countries if these emission allowances are traded.

To meet the global emission path of -30% (2030) and -80% (2050) a convergence at about 0.6 to 0.7 tCO_2eq per capita in 2050 is necessary (see Table 4). In this case the average per capita emissions will have to lie around 4.5 tCO_2eq per capita in 2020.

Table 4. Convergence levels of per capita emissions rights in tCO_2eq/cap in 2050 (the global emission level is the same but global population is different per scenario)

Scenario	Average in 2020 [tCO2eq/cap]	Convergence level in 2050 [tCO2eq/cap]
A1B	4.66	0.70
A1FI	4.67	0.70
A1T	4.61	0.73
A2	4.22	0.58
B1	4.39	0.74
B2	4.46	0.69

3.1.3 Common but differentiated convergence (CDC)

Common but differentiated convergence (CDC) is an approach presented by Höhne et al. (2006). Annex I countries' per capita emission allowances converge within, e.g., 40 years (2010 to 2050) to an equal level for all countries. Individual non-Annex I countries' per capita emissions also converge within the same period to the same level but convergence starts from the date, when their per capita emissions reach a certain percentage threshold of the (gradually declining) global average. Non-Annex I countries that do not pass this percentage threshold do not have binding emission reduction requirements. Either they take part in the CDM or they voluntarily take on positively binding emission reduction targets. Under the latter, emission allowances may be sold if the target is overachieved, but no emission allowances have to be bought if the target is not reached.

The CDC approach, similarly to C&C, aims at equal per capita allowances in the long run (see Figure 6). In contrast to C&C it considers more the historical responsibility of countries. Annex I countries would have to reduce emissions similarly to C&C, but many non-Annex I countries are likely to have more time to develop until they need to reduce emissions. Non-Annex I country participation is conditional to Annex I action through the gradually declining world average threshold. No excess emission allowances ("hot air") would be granted to least developed countries.

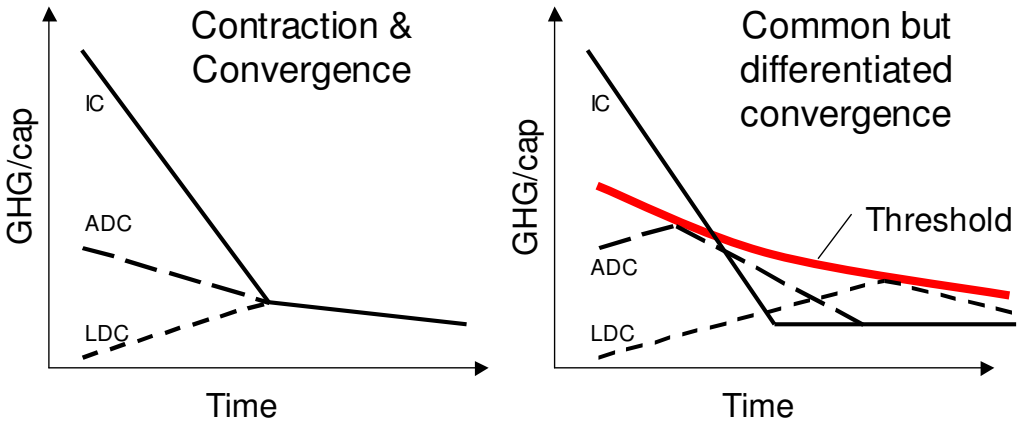


Figure 6. Schematic representation of GHG emissions per capita for three types of countries (an industrialized country (IC), an advanced developing country (ADC) and a least developed country (LDC)) under contraction and convergence (left) and under common but differentiated convergence (right)

The parameters for the convergence time, the threshold for participation and the convergence level used in this report are provided in Table 5.

Table 5. Parameters used for the Common but Differentiated Convergence approach

Parameter	Unit	A1B	A1FI	A1T	A2	B1	B2
Convergence time	Years	27	27	27	27	27	27
Threshold	% difference from world average	-35%	-35%	-35%	-31%	-22%	-24%
Convergence level	tCO_2eq/cap	0.64	0.64	0.64	0.42	0.51	0.52

3.1.4 Overview of all considered effort-sharing approaches

Table 6 below gives a short overview on strengths and weaknesses of the considered effort-sharing approaches Greenhouse Development Rights (GDRs), Contraction and Convergence (C&C) and Common but Differentiated Convergence (CDC).

Table 6. Strengths and weaknesses of the considered effort sharing approaches

	Strengths	Weaknesses
GDRs	• Uses historical emissions and GDP above a development threshold for differentiation • Uses share of wealthy population in a country as indicator for required action by that country • Assigns responsibility to reduce emissions abroad • Participation of all countries with the same rules • Includes cost-effective reduction options in developing countries through full international emissions trading	• Reduction below BAU assumes that the BAU is equitable • Possibly too simple and not considering detailed national circumstances
C&C	• Emphasis on a common endpoint: equal per capita emissions – does not require BAU • Participation of all countries with the same rules • Simple, clear concept • Includes cost-effective reduction options in developing countries through full international emissions trading • Support for least developed countries through excess emission rights	• Current per capita emissions is the only criterion for differentiation, does not consider differences in historical responsibility • National circumstances (including historical responsibility) not accommodated (optionally countries within one region can redistribute allowances to accommodate national concerns) • Substantial reduction for countries with high per capita emissions, also such developing countries • Also least developed countries need to be capable of participating in emissions trading to receive benefits (national greenhouse gas inventories and emission trading authorities)
CDC	• Emphasis on a common endpoint and equal path towards it: equal per capita emissions – does not require BAU • Applies simple rules, thus, making approach transparent • Delay of non-Annex I countries takes account of the responsibility for past emissions • Eliminates the component of "hot air" (no excess allowances for low emission countries)	• Per capita emissions is the only criterion for differentiation, but the delay of Non-Annex I countries accounts for differences in historical responsibility • National circumstances not accommodated, except per capita emissions and current membership of Annex I • Possibly too simple and not considering detailed national circumstances

3.2 Results

This chapter presents the results for emission rights for different countries and regions under the effort sharing approaches described before.

As all calculations consider six different reference scenarios based on the Special Report on Emission Scenarios from the IPCC (SRES, Nakicenovic et al. 2000). These scenarios include different assumptions concerning growth of GDP, population and other important factors. The bars in the figures indicate the median of the results from all scenarios; the error bars show the highest and lowest values.

Figure 7 shows the emission allowances in 2020 and 2050 as percentage change from 1990 for different reduction approaches. Figure 8 and Figure 9 give the same data as percentage changes from business as usual (BAU) and as emissions per capita, respectively.

Figure 10 shows cumulative emissions between 1990-2020 and 1990-2050 under different effort sharing approaches divided by the population in 2020 and 2050, respectively. Figure 11 gives the cumulative emissions between 1990-2020 and 1990-2050 under the different effort sharing methods. Figure 12 and Figure 13 show the development of national emission allowances between 1990 and 2020 under CDC, GDRs and C&C for Annex I and non-Annex I, respectively. Cumulative emissions are divided by the absolute number of people in that year. For 2020 this means for example that emissions are added from 1990 to 2020 and are then divided by the population of 2020.

All calculations and results comprise emissions *exclude* LUCF. The global emission budget described in Chapter 2 can be met, if in addition emissions from LUCF also follow the path described there (reduction to zero in 2020 and turning to a net sink in 2030 with constant level afterwards). Including LUCF would lead to changes in the distributions, which could be significant for countries with high emissions and/or removals in this sector, e.g. Brazil, USA and Russia.

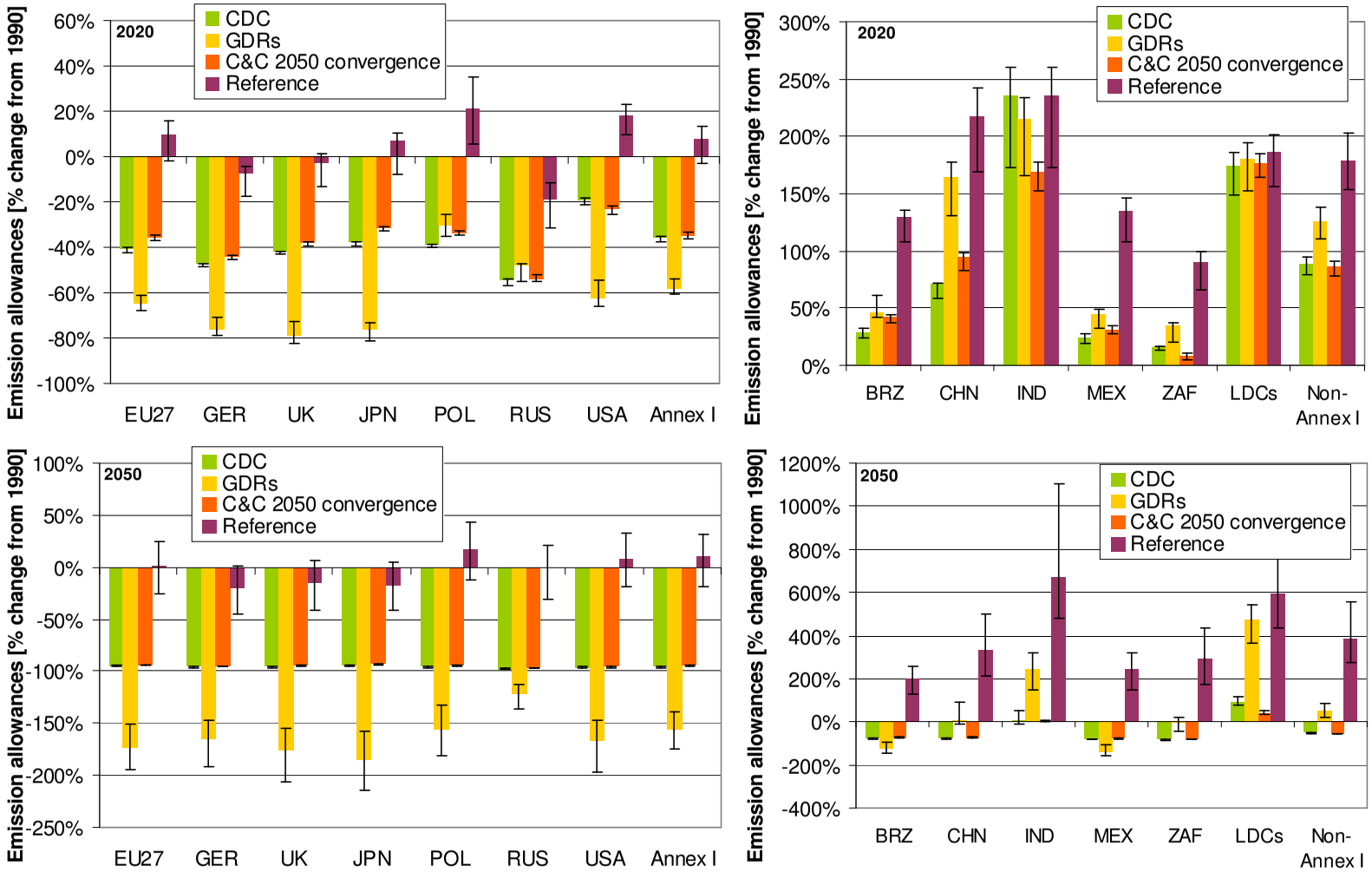


Figure 7. Emission allowances in 2020 and 2050 as percentage change from 1990 for different reduction approaches.

Note: EU27 (European Union), GER (Germany), UK (United Kingdom), JPN (Japan), RUS (Russia), POL (Poland), USA, Annex I, BRZ (Brazil), CHN (China), IND (India), MEX (Mexico), ZAF (South Africa), LDCs (least developed countries), non-Annex I. Data are included in Appendix B.

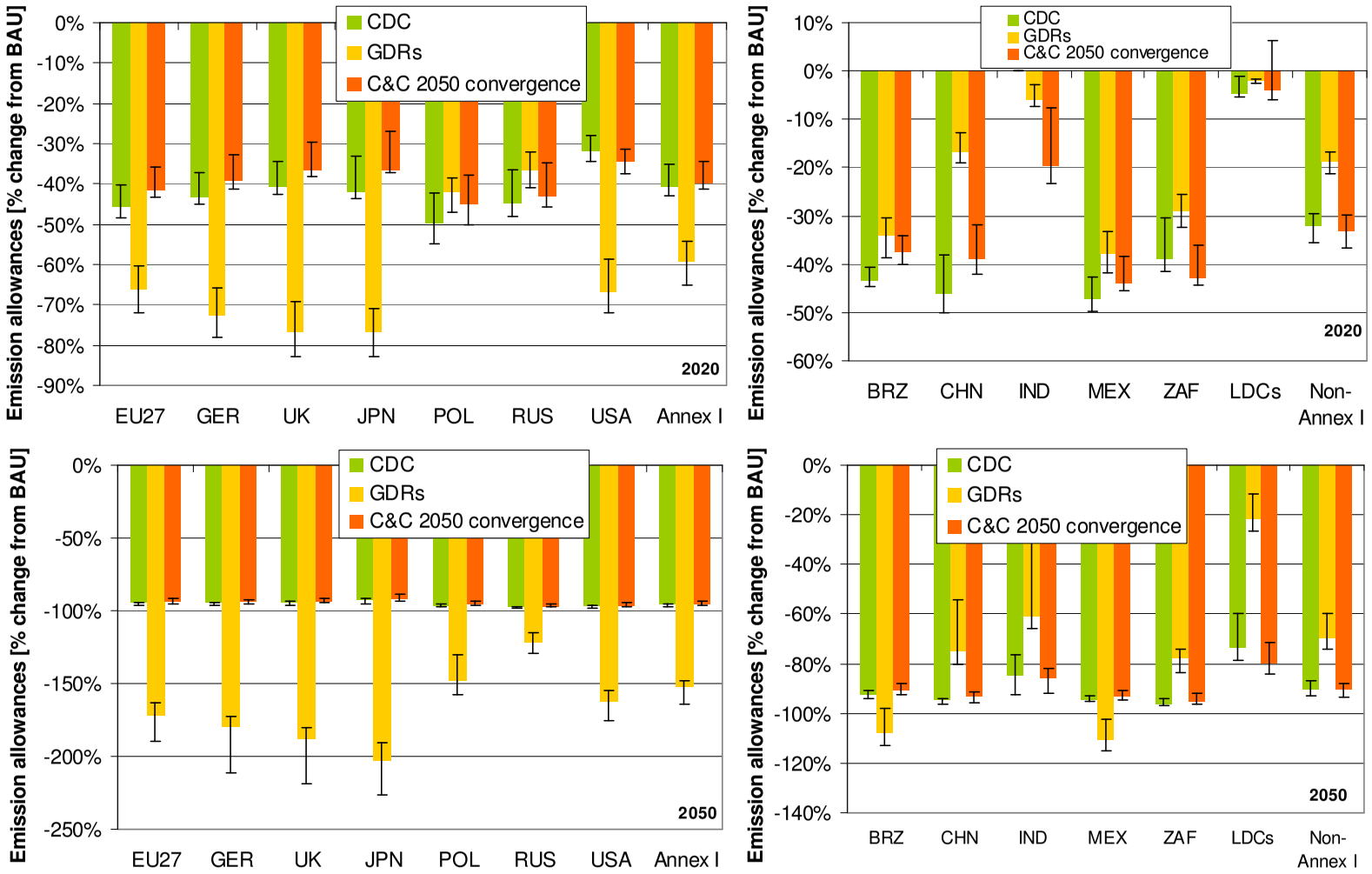


Figure 8. Emission allowances in 2020 and 2050 as percentage change from business as usual (BAU) for different reduction approaches.

Note: EU27 (European Union), GER (Germany), UK (United Kingdom), JPN (Japan), RUS (Russia), POL (Poland), USA, Annex I, BRZ (Brazil), CHN (China), IND (India), MEX (Mexico), ZAF (South Africa), LDCs (least developed countries), non-Annex I. Data are included in Appendix B.

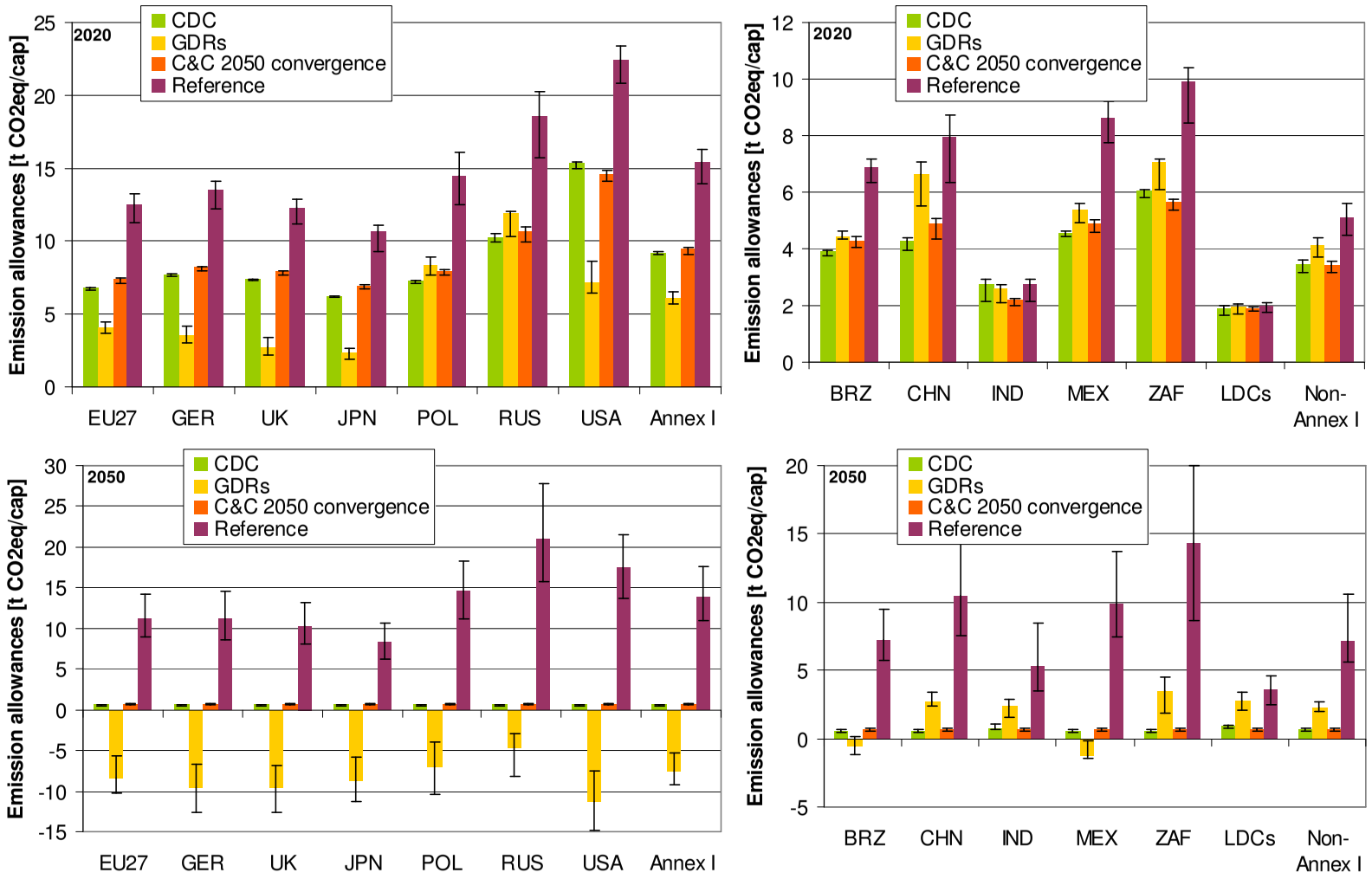


Figure 9. Emission allowances in 2020 and 2050 as emissions per capita for different reduction approaches.

Note: EU27 (European Union), GER (Germany), UK (United Kingdom), JPN (Japan), RUS (Russia), POL (Poland), USA, Annex I, BRZ (Brazil), CHN (China), IND (India), MEX (Mexico), ZAF (South Africa), LDCs (least developed countries), non-Annex I. Data are included in Appendix B.

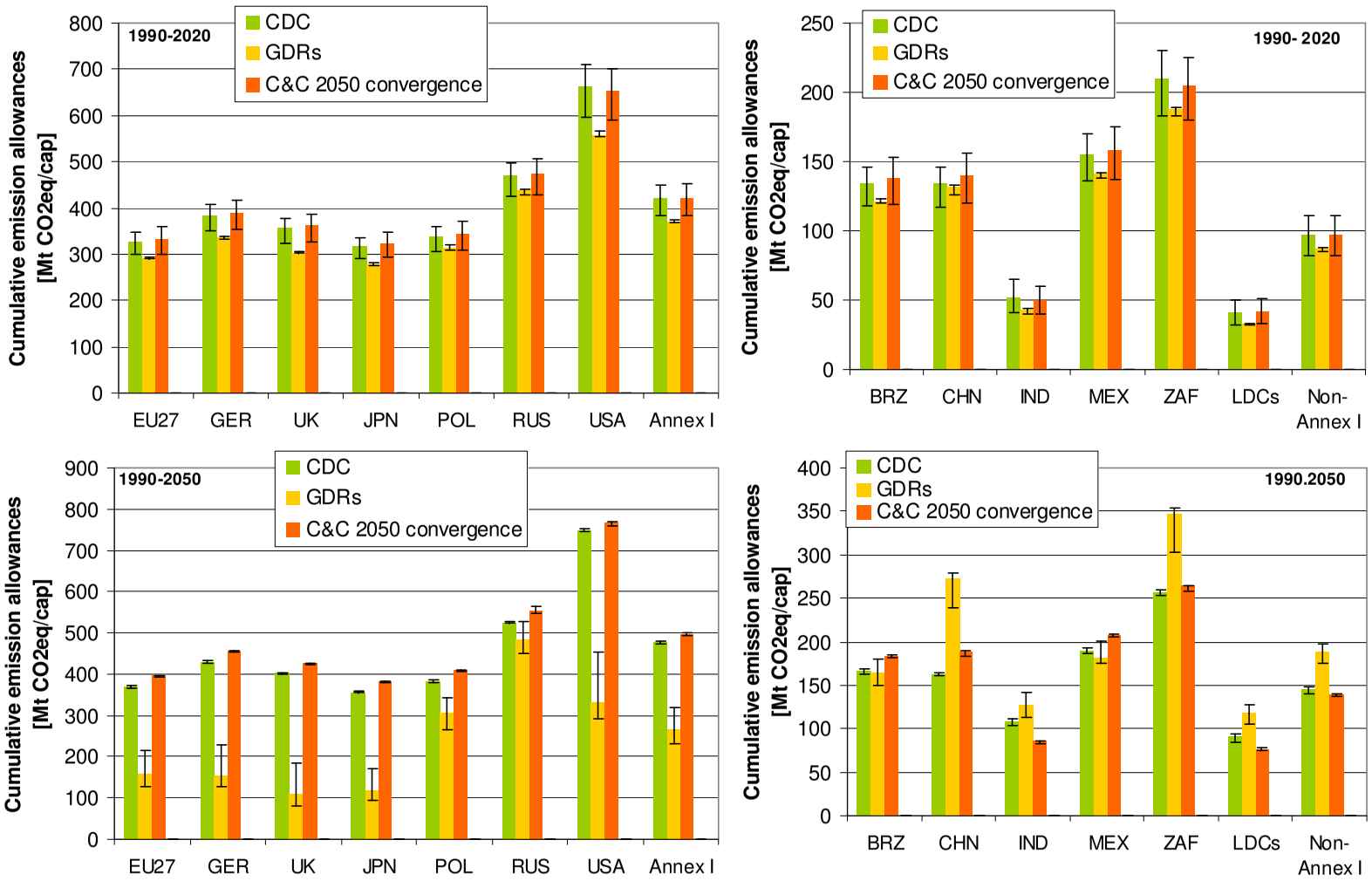


Figure 10. Cumulative emission allowances (1990-2020 and 1990-2050) per capita (2020 and 2050) different reduction approaches.

Note: EU27 (European Union), GER (Germany), UK (United Kingdom), JPN (Japan), RUS (Russia), POL (Poland), USA, Annex I, BRZ (Brazil), CHN (China), IND (India), MEX (Mexico), ZAF (South Africa), LDCs (least developed countries), non-Annex I. Data are included in Appendix B.

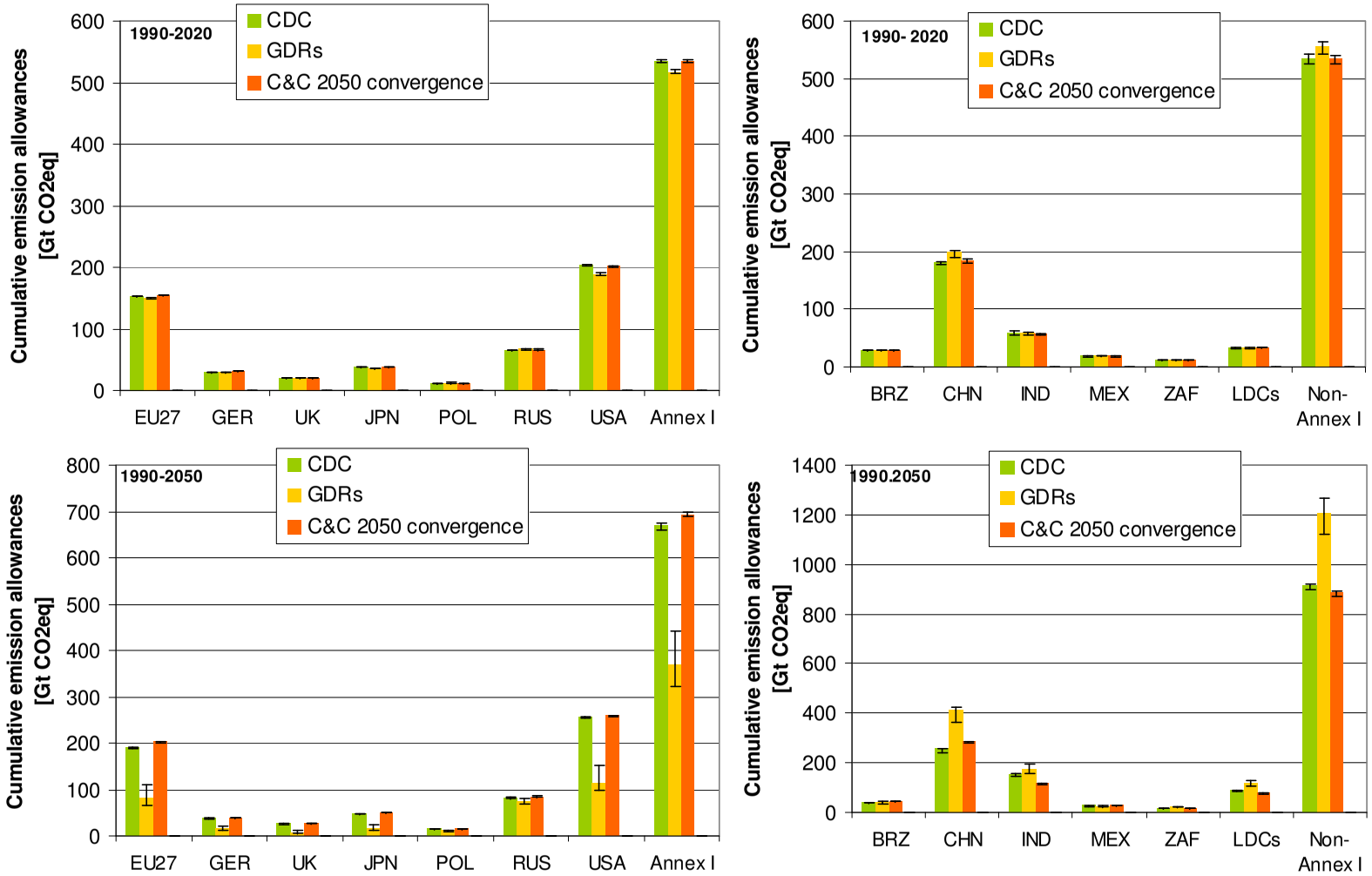


Figure 11. Cumulative emission allowances from 1990 to 2020 and 2050 for different reduction approaches.

Note: EU27 (European Union), GER (Germany), UK (United Kingdom), JPN (Japan), RUS (Russia), POL (Poland), USA, Annex I, BRZ (Brazil), CHN (China), IND (India), MEX (Mexico), ZAF (South Africa), LDCs (least developed countries), non-Annex I. Data are included in Appendix B.

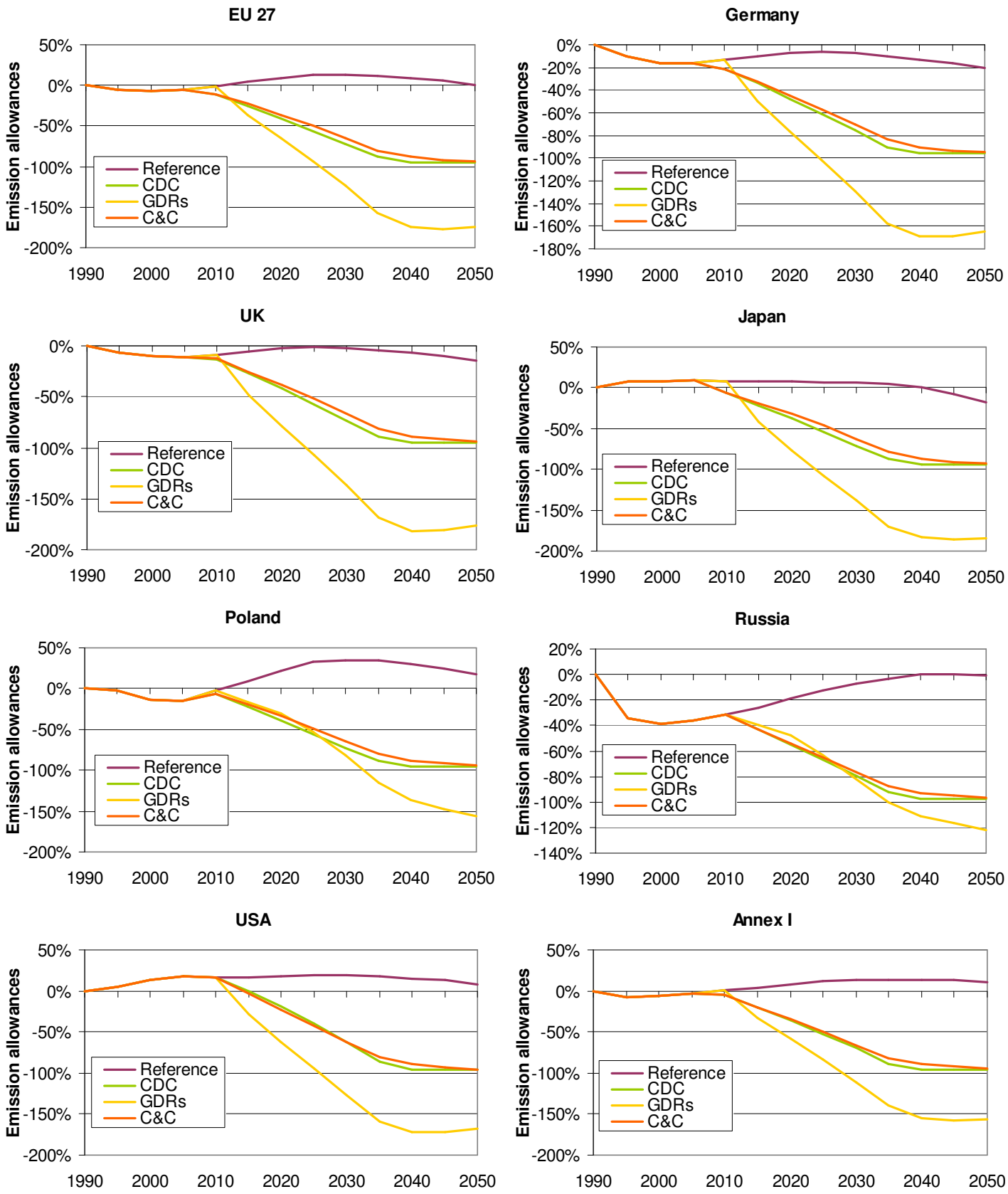


Figure 12. Development of national emission allowances as percentage change from 1990 emissions for Annex I between 1990 and 2050 under CDC, GDRs and C&C.

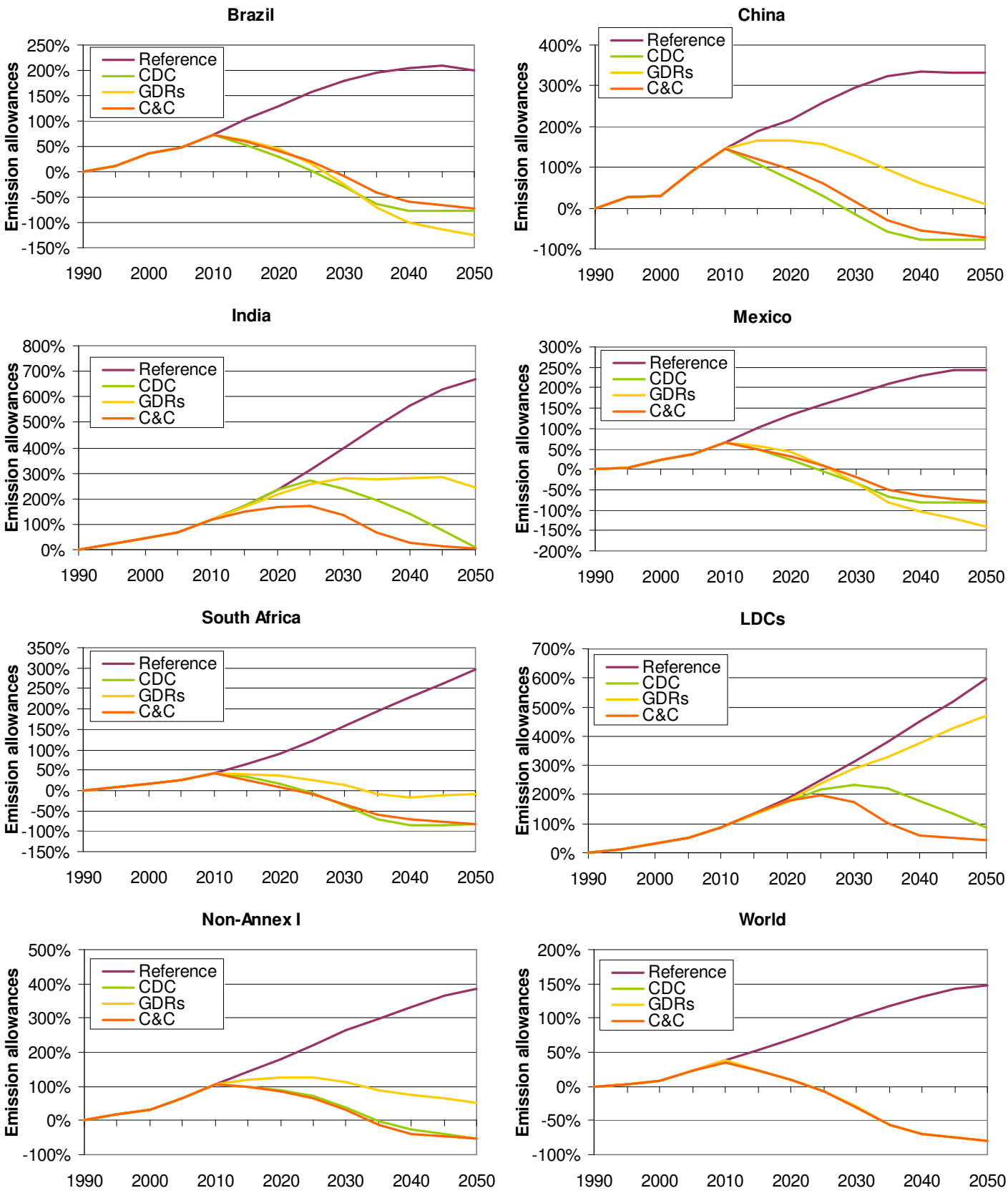


Figure 13. Development of national emission allowances as percentage change from 1990 emissions for non-Annex I and the world between 1990 and 2050 under CDC, GDRs and C&C.

4 Conclusions

The assumptions of -30% emission reduction below 1990 levels by 2020 and -80% by 2050 lead to a global GHG budget excluding LUCF of roughly 1800 Gt from 1990 to 2100. The requirements to reach this are very stringent. This is also reflected by the resulting target of about 0.5 tCO_2eq per capita as global average in 2050. In 2020 the average per capita emission lie around 9 tCO_2eq per capita for Annex I and 3-5 tCO_2eq per capita for non-Annex I.

Generally, the Greenhouse Development Rights approach (GDRs) allows negative emission where required reductions based on capacity and responsibility are larger than business as usual emissions. Contraction and Convergence (C&C) and Common but Differentiated Convergence (CDC) allow only very small but not negative emissions. Therefore, Annex I emission targets go to -60% in 2020 under the GDRs, while the other approaches require around -40%.

Hardly any differences can be seen for Annex I between C&C and CDC results. In the long term C&C leads to slightly less stringent results for high income and high emission countries.

By 2050, GDR requires Annex I countries as a group to reduce emissions by 157% and 'only' by 95% under C&C and CDC.

Developing countries and economies in transition (EITs) have more room to grow under GDRs than under the other approaches. The main reason for this is the relatively low per capita emissions combined with limited financial capacity.

LDCs are almost all exempt from emission reduction requirements under GDRs (+ >450% by 2050) , while under C&C they are granted little more allowances then their reference emissions until 2020 and face reduction obligations after 2025. Under CDC they face reductions after 2030.

Cumulative emissions per capita vary considerably under C&C and CDC for Annex I and non-Annex I. For GDRs some non-Annex I countries are granted higher per capita cumulative emissions than some countries of Annex I.

Under GDRs, non-Annex I countries are allowed to increase their total emissions and peak until 2025 and then need to reduce them to roughly today's level in 2050 (about 50% above 1990). Under C&C and CDC there is less room for growth and their emissions need to be at a third of today's emissions (half of 1990's emissions). This is reflected particular in the case of China and India. Both countries would be entitled under GDR to grow their emissions by 10% and even 240%, respectively by 2050 compared to 1990 but would be required to reduce by >70% and about 2-7% in same period under the other two models.

References

P. Baer, Athanasiou, T., and Kartha, S. (2007). *The right to development in a climate constrained world. The Greenhouse Development Rights framework*. Publication series on ecology, volume 1, Berlin: Heinrich-Böll-Foundation, Christian Aid, EcoEquity and the Stockholm Environment Institute.

P. Baer, Athanasiou, T., Kartha, S., and Kemp-Benedict, E. (2008). *The Greenhouse Development Rights framework. The right to development in a climate constrained world*. Revised second edition. Publication series on ecology, volume 1, Berlin: Heinrich-Böll-Foundation, Christian Aid, EcoEquity and the Stockholm Environment Institute.

GCI. (2005). *GCI Briefing: Contraction & Convergence*. Global Commons Institute.

Höhne, N., M. G. J. den Elzen, and M. Weiss. (2006). Common but differentiated convergence (CDC), a new conceptual approach to long-term climate policy. *Climate Policy*, *6* , 181-199.

R. A. Houghton. (2003). *Emissions (and Sinks) of Carbon from Land-Use Change. (Estimates of national sources and sinks of carbon resulting from changes in land use, 1950 to 2000)*. Report to the World Resources Institute from the Woods Hole Research Center, Woods Hole, Massachusetts, USA: Woods Hole Research Center.

IEA. (2008). *CO2 Emissions from Fuel Combustion (2008 edition).* International Energy Agency.

IMAGE team. (2001). *The IMAGE 2.2 implementation of the SRES scenarios. A comprehensive analysis of emissions, climate change and impacts in the 21st century*. CD-ROM publication 481508018, Bilthoven, the Netherlands:

M. Meinshausen. (2005). *On the risk of overshooting 2°C*. Paper presented at the Scientific Symposium "Avoiding Dangerous Climate Change", MetOffice,

A. Meyer. (2000). *Contraction & convergence. The global solution to climate change*. Schumacher Briefings, No. 5. Bristol, UK:

N. Nakicenovic, Alcamo, J., Davis, G., de Vries, B., Fenhann, J., Gaffin, S., Gregory, K., Grübler, A., Jung, T. Y., Kram, T., Emilio la Rovere, E., Michaelis, L., Mori, S., Morita, T., Pepper, W., Pitcher, H., Price, L., Riahi, K., Roehrl, A., Rogner, H., Sankovski, A., Schlesinger, M., Shukla, P., Smith, S., Swart, R., van Rooyen, S., Victor, N., and Dadi, Z. (2000). *Special report on emissions scenarios.* Cambridge, UK: Cambridge University Press.

Niklas Höhne and Sara Moltmann. (2008). *Distribution of emission allowances under the greenhouse development rights and other effort sharing approaches*. http://www.boell.de/ecology/resources/resource-governance-ecology-5430.html.

J. G. J. Olivier and J. J. M. Berdowski. (2001). Global emissions sources and sinks. In Berdowski, J., Guicherit, R., and Heij, B. J. (Eds.), *The Climate System* pp. 33-78) A.A. Balkema Publishers/Swets & Zeitlinger Publishers, Lisse, The Netherlands. ISBN 90 5809 255 0.

UN. (2008). *World Population Prospects: the 2008 revision*. United Nations Department for Economic and Social Information and Policy Analysis, New York, USA.

UNFCCC. (2008). *Greenhouse gas inventories submitted to the UNFCCC*. UNFCCC.

USEPA. (2006). *Global Anthropogenic Non-CO2 Greenhouse Gas Emissions: 1990 – 2020*. Appendix A-D, Washington, D.C., USA: United States Environmental Protection Agency. http://www.epa.gov/climatechange/economics/downloads/GlobalMitigationFullReport.pdf.

World Bank. (2008). *World Development Indicators 2008.* Washington D.C.: World Bank.

Appendix A Description of the EVOC tool

This section describes the Evolution of Commitments tool (EVOC) version 8, developed by Ecofys, that is used to quantify emission allowances under the various approaches in this report. It includes emissions of CO_2, CH_4, N_2O, hydroflourocarbons (HFCs), perflourocarbons (PFCs) and sulphur hexafluoride (SF_6) for 192 individual countries. Historical emissions are based on national emission inventories submitted to the UNFCCC and, where not available, other sources such as the International Energy Agency. Future emissions are based on the IPCC Special Report on Emissions Scenarios (Nakicenovic et al. 2000). The greenhouse gas emission data for 1990 to 2006 is derived by an algorithm that combines emission estimates from various sources.

We first collected historical emission estimates by country, by gas and by sector from the following sources and ordered them in the following hierarchy:

1. National submissions to the UNFCCC as collected by the UNFCCC secretariat and published in the GHG emission database available at their web site. For Annex I countries, the latest available year is usually 2004. Most non-Annex I countries report only or until 1994 (UNFCCC 2008).
2. CO_2 emissions from fuel combustion as published by the International Energy Agency. The latest available year is 2003 (IEA 2008).
3. Emissions from land-use change as published by Houghton in the WRI climate indicator analysis tool (Houghton 2003).
4. Emissions from CH_4 and N_2O as estimated by the US Environmental Protection Agency. Latest available year is 2005 (USEPA 2006)
5. CO_2, CH_4, N_2O, HFC, PFC and SF_6 emissions from the EDGAR database version 3.2 available for 1990 and 1995 (Olivier and Berdowski 2001).[1]

Future emissions are derived from the MNP/RIVM IMAGE implementation of the SRES scenarios (IMAGE team 2001).

The datasets vary in their completeness and sectoral split. We first defined which of the sectors provided in the datasets correspond to 7 sectors. This definition is provided in Table 1. Note that CO_2 emissions from the IEA do not include process emissions from cement production. Hence, if IEA data is chosen, process emissions from cement production are not included.

For each country, gas and sector, the algorithm completes the following steps:

1. For all data sets, missing years in-between available years within a data set are linearly interpolated and the growth rate is calculated for each year step.
2. The data source is selected, which is highest in hierarchy and for which emission data are available. All available data points are chosen as the basis for absolute emissions.
3. Still missing years are filled by applying the growth rates from the highest data set in the hierarchy for which a growth rate is available.

[1] For CH_4 and N_2O, the values of EPA are largely based on the EDGAR database (1990 and 1995), but extended to the year 2000.

As future emissions are only available on a regional basis and not country-by-country, the resulting set of emissions is then extended into the future by applying the growth rates of the respective sectors and gas of the region to which the country belongs. (See Table 1 for detailed information on data sources and definition of sectors.)

For population, GDP in purchase power parities and electricity demand, the country base year data was taken from the United Nations (UN 2008), World Bank (2008) and IEA (2008), respectively. These data are extended into the future by applying the growth rates from the IMAGE model for the region to which the country belongs.

Emissions until 2010 are estimated as follows: It is assumed that Annex I countries implement their Kyoto targets by 2010. It is assumed that the reductions necessary to meet the Kyoto target are achieved equally in all sectors. In 2010, the level of the domestic sector is taken from the relevant reference scenario. The level of the other sectors are taken from the reference scenario and reduced, so that the Kyoto target is met. The years from the last available year to 2010 are linearly interpolated. All non-Annex I countries follow their reference scenario until 2010.

Table 1. Data sources and definition of sectors

	UNFCCC		Edgar 3.2 database		USEPA		LUCF Houghton		IEA		IMAGE CD	
	Regional:	country by country	**Regional:**	country by country	**Regional:**	country-by country	**Regional:**	country-by country	**Regional:**	country by country	**Regional:**	17 regions
	Temporal:	1990 to 2002 (various)	**Temporal:**	1990 and 1995	**Temporal:**	1990-2020	**Temporal:**	1950-2000	**Temporal:**	1970-2000	**Temporal:**	1970 to 2100
	Gas:	CO2, CH4, N2O, HFCs, PFCs, SF6	**Gas:**	CO2, CH4, N2O; HFCs, PFCS, SF6	**Gas:**	CH4, N2O	**Gas:**	CO2	**Gas:**	CO2	**Gas:**	CO2, CH4, N2O, HFCs, PFCs, SF6
Industry												
	1A2	Manufacturing Industries and Construction	**F10**	Industry					3T Other Energy Industries		ENERGY 01 Industry	
	2A0	Mineral Products	**F30**	Other transformation sectors					401 Iron and Steel		ENERGY 07 Other energy transformation	
	2B0	Chemical Industry	**B10CH4N2O**	Biofuel industry CH4 N2O					402 Chemical and Petrochemical		INDUS 01 Feedstocks	
	2C0	Metal Production	**B30CH4N2O**	Biofuel charcoal production CH4 N2O					403 Non-Ferrous Metals		INDUS 02 Industrial activities	
	2D0	Other Production	**I10**	Iron and steel					404 Non-Metallic Minerals			
	2G0	Other (Industrial Processes)	**I20**	Non-ferrous metals					409 Paper, Pulp and Printing			
			I30	Chemicals					405 Transport Equipment			
			I40	Building materials					406 Machinery			
			I50	Pulp and psper					407 Mining and Quarrying			
			I60	Food					408 Food and Tobacco			
			I70	Solvent use/Miscellaneous					410Wood and Wood Products			
			I80	Transport evaporation					411 Construction			
			I90	Miscellanecus industry					412 Textile and Leather			
			F60	non-energy use and feedstocks					413 Non-specified Industry			
									414 Non-Energy Use Ind/Transf/Energy			
									If the IEA data set is chosen, process emissions from industry (e.g. from cement) are not covered			
Electricity												
	1A1	Energy Industries	**F20**	Power generation					11 Public Electricity Plants		ENERGY 06 Electric power generation	
			B20CH4N2O	Biofuel power generation CH4 N2O					12 Public CHP Plants			
									13 Public Heat Plants			
									14 Own Use in Electricity, CHP and heat plants			
									21 Autoproducer Electricity Plants			
									22 Autoproducer CHP Plants			
									23 Autoproducer Heat Plants			
Domestic												
	1A3	Transport	**F40**	Residential, commercial and other sectors					5T Transport		ENERGY 02 Transport	
	1A4	Other Sectors (Fuel Combustion)	**F51**	Transport road					6T Other Sectors		ENERGY 03 Residential (households)	
	1A5	Other (Fuel Combustion)	**F54**	Transport land non-road					*MB Memo: International Marine Bunkers*		ENERGY 04 Services (commercial and public)	
	2E0	Production of Halocarbons and Sulphur Hexafluoride	**F57**	Transport air (international and domestic)					*AB Memo: International Aviation Bunkers*		ENERGY 05 Agriculture and other enduse	
	2F0	Consumption of Halocarbons and Sulphur Hexafluoride	***F58***	*Transport international shipping*							*ENERGY 09 Marine bunkers*	
	3TT	TOTAL Solvent and Other Product Use	**B40CH4N2O**	Biofuel residential CH4 N2O							FGAS	
	9TT	*TOTAL International Bunkers*	**B51CH4N2O**	Biofuel transport road CH4 N2O								
			C10	HFC-byproc								
			C20	HFC use								
			C30	PFC-byproc								
			C40	PFC use								
			C50	SF6 use								
	Secotors in italics are excluded when the user chooses to exclude international transport											
Fossil fuel production												
	1BT	TOTAL Fugitive Emissions from Fuels	**F70**	Coal production	02 Coal production				7T Differences due to Losses and/or Transformation		ENERGY 08 Fossil fuel production	
			F80	Oil production, transmission and handling	03 Natural gas production							
			F90	Gas production and transmission	04 Oil production							
			F95	Fossil fuel fres								
Agriculture												
	4TT	TOTAL Agriculture	**L10**	Fertiliser use	06 Manure management						LAND 10 wetland rice	
			L15	Rice cultivation	07 Enteric fermentation						LAND 11 animals	
			L20	Enteric fermentation	08 Rice production						LAND 12 animal waste	
			L30	Animal waste management (confined N2O, all CH4)	09 Agricultural soils						LAND 14 fertilizer	
			L50	Crop production							LAND 15 indirect fertilizer	
			L60	Animal waste management (deposited on soil- N2O)							LAND 16 indirect animal waste	
			L71	Atmospheric deposition							LAND 17 crop residues	
			L75	Leaching and run-off							LAND 18 biological N-fixation	
LUCF												
	5TT	TOTAL Land-Use Change & Forestry	**L41**	BB-Deforestation	10 Biomass combustion		Land-use				LAND 01 biomass burning	
			L42	BB-Savanna burning							LAND 02 burning of traditional biomass / fuelwood burning	
			L43	BB-Agricultural waste burning							LAND 03 timber pool (short lifetime)	
			L44	BB-Vegetation fires							LAND 04 timber pool (long lifetime)	
			L45	BB-deforestation post burn effects							LAND 05 carbon release by regrowing vegetation (-NEP)	
											LAND 06 agricultural waste burning	
											LAND 07 savanna burning	
											LAND 13 land clearing	
Waste												
	6TT	TOTAL Waste	**W10**	Landfills	11 Landfills						LAND 08 landfills	
			W15	Humans/pets	12 Wastewater						LAND 09 (domestic) sewage	
			W20	Waste water treatment								
			W30	Human waste disposal								
			W40	Waste incireration								
			W50	Miscelaneous waste handling (hazardous waste)								
	CO2 emissions from Biaomass buring (UNFCCC sector 1A8 and EGRAR sectors B10 to B51) are not included as they are not to be included in the national totals according to teh IPCC guidelines and the UNFCCC repsoting guidelines)											

As a default setting, all Annex I countries are assumed to reach the lower of their Kyoto target and their reference scenarios in 2010. Only the USA is assumed to follow its BAU emissions until 2010. All non-Annex I countries also follow their reference scenario until 2010. After 2010, the emission allowances per country are calculated according to the effort sharing approaches.

A limitation of the tool is the unknown future development of emissions of individual countries. Here, we have used the standard set of future emissions scenarios, the IPCC SRES scenarios, as a basis. They provide a broad range of storylines and therefore a wide range of possible future emissions. We cover this full range of possible future emissions, economic and population development in a consistent manner. But the SRES scenarios are only available at the level of up to 17 regions (as in the IMAGE implementation) and scaling them down to individual countries introduces an additional element of uncertainty. We applied the growth rates provided for 17 world regions to the latest available data points of the individual countries within the respective regions. So, on the level of regions, we cover the full-range uncertainty about future emissions. When again aggregating the regions, the effect of downscaling cancels out. But the full level of uncertainty is not covered on the national level as substantial differences may exist for expected growth for countries within one of the 17 regions.

The future reference development of emissions, economic and population is affected by the starting values (which is data available from the countries or other international sources and which can be substantially different for countries in one region) and the assumed growth rates (which are derived from the 17 regions).

The assumed growth rates may affect the results of countries to a different extent. Some countries are less affected as they dominate their regional group, such as Brazil, Mexico, Egypt, South Africa, Nigeria, Saudi Arabia, China and India. It is for second or third largest countries in a region or for members of an inhomogeneous group, for which this method may lead to an over or underestimation of the future development.

Second or third largest countries in a region are e.g. Argentina, Venezuela, United Arab Emirates and South Korea. In the Contraction and Convergence approach, the error would be small as countries follow their reference scenario only until 2010 and converge afterwards. For Common but Differentiated Convergence and Multistage, the downscaling method may influence the time of participation. But the countries listed above would all participate at the earliest possible moment, based on their already today high per capita emissions. In the Triptych approach, growth in industrial and electricity production and a reduction below reference for agriculture is used, which may be affected by the downscaling method.

Members of an inhomogeneous group would be those of South East Asia, which includes Indonesia and the Philippines as lower-income countries and Malaysia, Singapore and Thailand as higher-income countries. Here the growth is averaged over the region, probably underestimated for Indonesia and the Philippines and overestimated for Singapore. The dominant element here is the starting point. The low per capita emissions of the Philippines and Indonesia lead to their late participation, while the high per capita emissions in Malaysia, Singapore and Thailand lead to their immediate participation. In the Triptych approach, growth in industrial and electricity production and a reduction below reference for agriculture is used, which may be affected by the downscaling method.

For Annex I countries, the future reference development is not as relevant since they always participate in the regime on the highest stage and have to reduce emissions independent of the reference development. Future values are only relevant for intensity targets (GDP) or for the Triptych approach (industrial and electricity production).

A different uncertainty is introduced since our future emissions are static, meaning that emissions in non-participating developing countries do not change as a result of

ambitious or relaxed emission reductions in developed countries. Stringent reductions could affect emissions of non-participating countries in two ways. There could be increased emissions through migration of energy-intensive industries or decreased emissions due to technology spill-over. Overall, we assume that this effect is small and not significantly influencing the results of this analysis.

Appendix B Emission allowances distributed with EVOC

For methodological reasons an overall carbon budget of 1600 Gt by 2050 is assumed instead of 1660 Gt by 2050 as estimated in Chapter 2.

Table 2. Emission allowances as percentage change from 1990 for 2020 and 2050 under CDC, C&C and GDRs excluding LUCF

	Emissions [Mt CO2 eq.]			CDC			GDRs			C&C 2050 convergence			Reference		
				% change from 1990			% change from 1990			% change from 1990			% change from 1990		
Year	1990	2000	2010	2020			2020			2020			2020		
Country group			BAU	Min	Median	Max	Min	Median	Max	Min	Median	Max	Min	Median	Max
World	31196	33764	43250	6%	10%	12%	6%	10%	12%	6%	10%	12%	55%	68%	83%
EU27	5802	5371	5767	-42%	-41%	-40%	-68%	-65%	-61%	-37%	-36%	-35%	-2%	9%	16%
GER	1253	1055	1086	-49%	-48%	-47%	-79%	-76%	-71%	-45%	-44%	-44%	-18%	-8%	-4%
UK	800	718	731	-43%	-42%	-42%	-83%	-79%	-73%	-39%	-38%	-37%	-13%	-3%	1%
JPN	1318	1427	1423	-39%	-38%	-38%	-81%	-76%	-73%	-33%	-32%	-31%	-8%	7%	11%
POL	456	392	445	-40%	-39%	-39%	-35%	-30%	-25%	-35%	-34%	-32%	5%	21%	35%
RUS	3361	2060	2288	-57%	-55%	-54%	-55%	-48%	-47%	-55%	-54%	-52%	-31%	-19%	-12%
USA	6341	7240	7403	-21%	-19%	-18%	-66%	-62%	-54%	-26%	-23%	-22%	10%	18%	23%
Annex I	19699	18545	19746	-37%	-36%	-35%	-60%	-58%	-54%	-37%	-35%	-33%	-3%	8%	13%
BRZ	680	931	1175	24%	29%	33%	42%	45%	61%	37%	42%	45%	108%	130%	135%
CHN	3546	4604	8703	59%	71%	73%	130%	165%	177%	82%	94%	98%	169%	218%	242%
IND	1087	1560	2343	173%	235%	261%	165%	215%	234%	152%	169%	177%	173%	235%	261%
MEX	457	562	763	19%	23%	27%	32%	44%	49%	27%	31%	34%	107%	135%	146%
ZAF	337	391	483	14%	16%	17%	21%	35%	37%	5%	8%	11%	66%	90%	99%
LDCs	682	888	1270	149%	174%	186%	152%	180%	195%	165%	176%	184%	156%	186%	202%
Non-Annex I	11263	14850	23124	79%	89%	95%	111%	126%	138%	78%	86%	91%	154%	179%	202%

	Emissions [Mt CO2 eq.]			CDC			GDRs			C&C 2050 convergence			Reference		
				% change from 1990			% change from 1990			% change from 1990			% change from 1990		
	1990	2000	2010	2050			2050			2050			2050		
			BAU	Min	Median	Max	Min	Median	Max	Min	Median	Max	Min	Median	Max
World	31196	33764	43250	-80%	-80%	-80%	-80%	-80%	-80%	-80%	-80%	-80%	90%	148%	225%
EU27	5802	5371	5767	-96%	-95%	-94%	-195%	-174%	-151%	-95%	-94%	-94%	-25%	1%	25%
GER	1253	1055	1086	-97%	-96%	-96%	-193%	-165%	-147%	-96%	-95%	-95%	-45%	-20%	1%
UK	800	718	731	-96%	-95%	-95%	-206%	-176%	-155%	-95%	-94%	-94%	-41%	-15%	6%
JPN	1318	1427	1423	-96%	-94%	-94%	-214%	-185%	-158%	-94%	-93%	-93%	-41%	-18%	5%
POL	456	392	445	-97%	-95%	-95%	-182%	-156%	-132%	-95%	-94%	-94%	-13%	17%	43%
RUS	3361	2060	2288	-98%	-97%	-97%	-136%	-122%	-112%	-97%	-97%	-97%	-31%	-1%	20%
USA	6341	7240	7403	-97%	-96%	-96%	-198%	-167%	-147%	-96%	-96%	-95%	-19%	8%	32%
Annex I	19699	18545	19746	-97%	-96%	-95%	-175%	-157%	-139%	-95%	-95%	-95%	-18%	10%	31%
BRZ	680	931	1175	-81%	-77%	-76%	-145%	-125%	-95%	-74%	-73%	-70%	131%	201%	256%
CHN	3546	4604	8703	-81%	-76%	-76%	-10%	10%	92%	-74%	-73%	-67%	209%	331%	497%
IND	1087	1560	2343	-8%	7%	51%	146%	242%	323%	1%	2%	5%	478%	669%	1108%
MEX	457	562	763	-84%	-81%	-80%	-156%	-140%	-106%	-78%	-78%	-75%	145%	243%	321%
ZAF	337	391	483	-87%	-83%	-83%	-41%	-7%	19%	-82%	-81%	-78%	173%	295%	434%
LDCs	682	888	1270	80%	88%	115%	362%	472%	544%	35%	43%	54%	433%	596%	778%
Non-Annex I	11263	14850	23124	-55%	-52%	-50%	23%	51%	85%	-56%	-54%	-53%	278%	386%	557%

Table 3. Emission allowances as percentage change from BAU for 2020 and 2050 under CDC, C&C and GDRs excluding LUCF

	Emissions [Mt CO2 eq.]			CDC			GDRs			C&C 2050 convergence			Reference		
				% change from BAU			% change from BAU			% change from BAU			% change from BAU		
Year	1990	2000	2010	2020			2020			2020			2020		
Country group			BAU	Min	Median	Max	Min	Median	Max	Min	Median	Max	Min	Median	Max
World	31196	33764	43250	-39%	-35%	-32%	-39%	-35%	-32%	-39%	-35%	-32%			
EU27	5802	5371	5767	-48%	-46%	-40%	-72%	-66%	-60%	-43%	-42%	-36%			
GER	1253	1055	1086	-45%	-43%	-37%	-78%	-73%	-66%	-41%	-39%	-33%			
UK	800	718	731	-43%	-40%	-35%	-83%	-77%	-69%	-38%	-36%	-30%			
JPN	1318	1427	1423	-44%	-42%	-33%	-83%	-77%	-71%	-37%	-36%	-27%			
POL	456	392	445	-55%	-50%	-42%	-47%	-42%	-38%	-50%	-45%	-38%			
RUS	3361	2060	2288	-48%	-45%	-37%	-41%	-37%	-32%	-46%	-43%	-35%			
USA	6341	7240	7403	-34%	-32%	-28%	-72%	-67%	-59%	-37%	-34%	-31%			
Annex I	19699	18545	19746	-43%	-40%	-35%	-65%	-59%	-54%	-41%	-40%	-34%			
BRZ	680	931	1175	-45%	-44%	-41%	-39%	-34%	-30%	-40%	-38%	-34%			
CHN	3546	4604	8703	-50%	-46%	-38%	-19%	-17%	-13%	-42%	-39%	-32%			
IND	1087	1560	2343				-7%	-6%	-3%	-23%	-20%	-8%			
MEX	457	562	763	-50%	-47%	-43%	-42%	-38%	-33%	-45%	-44%	-38%			
ZAF	337	391	483	-41%	-39%	-31%	-32%	-29%	-25%	-44%	-43%	-36%			
LDCs	682	888	1270	-5%	-5%	-1%	-2%	-2%	-2%	-6%	-4%	6%			
Non-Annex I	11263	14850	23124	-36%	-32%	-29%	-21%	-19%	-17%	-37%	-33%	-30%			

	Emissions [Mt CO2 eq.]			CDC			GDRs			C&C 2050 convergence			Reference		
				% change from BAU			% change from BAU			% change from BAU			% change from BAU		
	1990	2000	2010	2050			2050			2050			2050		
			BAU	Min	Median	Max	Min	Median	Max	Min	Median	Max	Min	Median	Max
World	31196	33764	43250	-94%	-92%	-89%	-94%	-92%	-89%	-94%	-92%	-89%			
EU27	5802	5371	5767	-96%	-95%	-94%	-190%	-172%	-164%	-95%	-94%	-92%			
GER	1253	1055	1086	-96%	-95%	-94%	-211%	-180%	-173%	-95%	-94%	-92%			
UK	800	718	731	-96%	-94%	-94%	-219%	-188%	-181%	-95%	-93%	-91%			
JPN	1318	1427	1423	-95%	-92%	-92%	-226%	-203%	-190%	-94%	-91%	-88%			
POL	456	392	445	-97%	-96%	-95%	-157%	-148%	-130%	-96%	-95%	-93%			
RUS	3361	2060	2288	-98%	-97%	-97%	-130%	-122%	-115%	-97%	-97%	-95%			
USA	6341	7240	7403	-98%	-96%	-96%	-176%	-162%	-155%	-97%	-96%	-95%			
Annex I	19699	18545	19746	-97%	-96%	-95%	-164%	-152%	-148%	-96%	-95%	-93%			
BRZ	680	931	1175	-94%	-92%	-91%	-113%	-108%	-98%	-93%	-91%	-88%			
CHN	3546	4604	8703	-96%	-95%	-94%	-80%	-75%	-54%	-96%	-93%	-91%			
IND	1087	1560	2343	-92%	-85%	-76%	-66%	-61%	-29%	-92%	-86%	-82%			
MEX	457	562	763	-95%	-95%	-93%	-115%	-111%	-102%	-95%	-93%	-91%			
ZAF	337	391	483	-97%	-96%	-94%	-84%	-78%	-74%	-96%	-95%	-92%			
LDCs	682	888	1270	-79%	-73%	-60%	-27%	-21%	-11%	-84%	-80%	-71%			
Non-Annex I	11263	14850	23124	-93%	-90%	-87%	-74%	-70%	-60%	-93%	-90%	-88%			

Table 4. Emission allowances as per capita emissions for 2020 and 2050 under CDC, C&C and GDRs excluding LUCF

	Emissions [t CO2eq./cap]			CDC t CO2eq./cap 2020			GDRs t CO2eq./cap 2020			C&C 2050 convergence t CO2eq./cap 2020			Reference t CO2eq./cap 2020		
Year	1990	2000	2010												
Country group		incl. Kyoto target		Min	Median	Max	Min	Median	Max	Min	Median	Max	Min	Median	Max
World	6.0	5.6	6.2	4.2	4.5	4.7	4.2	4.5	4.7	4.2	4.5	4.7	6.4	6.9	7.6
EU27	12.3	11.1	10.4	6.7	6.8	6.8	3.7	4.1	4.4	7.1	7.4	7.5	11.2	12.5	13.2
GER	15.8	12.8	11.9	7.6	7.7	7.7	3.1	3.5	4.2	8.0	8.2	8.3	12.2	13.5	14.1
UK	13.9	12.0	11.4	7.3	7.4	7.4	2.2	2.7	3.4	7.7	7.9	8.0	11.2	12.3	12.9
JPN	10.7	11.3	9.6	6.2	6.3	6.3	1.9	2.4	2.7	6.7	6.9	7.0	9.3	10.7	11.1
POL	12.0	10.2	11.2	7.1	7.2	7.3	7.7	8.3	8.9	7.7	7.9	8.0	12.5	14.5	16.1
RUS	22.7	14.1	15.9	9.9	10.2	10.5	10.3	11.9	12.0	10.0	10.7	11.0	15.7	18.5	20.2
USA	25.4	25.7	24.0	14.9	15.3	15.4	6.4	7.2	8.7	14.1	14.6	14.9	20.9	22.5	23.4
Annex I	16.5	14.9	14.2	9.1	9.2	9.3	5.7	6.1	6.5	9.1	9.4	9.6	14.0	15.4	16.3
BRZ	4.5	5.3	5.9	3.8	3.9	4.0	4.3	4.5	4.6	4.0	4.3	4.4	6.4	6.9	7.2
CHN	3.1	3.6	6.5	3.9	4.3	4.4	5.5	6.6	7.1	4.3	4.9	5.1	6.4	8.0	8.7
IND	1.3	1.5	2.0	2.2	2.7	2.9	2.1	2.6	2.7	2.0	2.2	2.3	2.2	2.7	2.9
MEX	5.5	5.7	6.9	4.4	4.5	4.7	4.9	5.4	5.6	4.6	4.9	5.0	7.7	8.6	9.2
ZAF	9.6	8.9	9.2	5.8	6.0	6.1	6.1	7.1	7.2	5.4	5.6	5.8	8.4	9.9	10.4
LDCs	1.3	1.3	1.5	1.7	1.9	2.0	1.7	1.9	2.0	1.8	1.9	2.0	1.7	2.0	2.1
Non-Annex I	2.8	3.1	4.3	3.2	3.5	3.6	3.7	4.2	4.4	3.2	3.4	3.5	4.5	5.1	5.6

	Emissions [t CO2eq./cap]			CDC t CO2eq./cap 2050			GDRs t CO2eq./cap 2050			C&C 2050 convergence t CO2eq./cap 2050			Reference t CO2eq./cap 2050		
	1990	2000	2010												
		incl. Kyoto target		Min	Median	Max	Min	Median	Max	Min	Median	Max	Min	Median	Max
World	6.0	5.6	6.2	0.6	0.7	0.7	0.6	0.7	0.7	0.6	0.7	0.7	6.5	8.1	11.7
EU27	12.3	11.1	10.4	0.4	0.6	0.6	-10.3	-8.4	-5.7	0.6	0.7	0.7	9.0	11.1	14.1
GER	15.8	12.8	11.9	0.4	0.6	0.6	-12.7	-9.5	-6.7	0.6	0.7	0.7	8.6	11.2	14.5
UK	13.9	12.0	11.4	0.4	0.6	0.6	-12.6	-9.6	-6.9	0.6	0.7	0.7	8.0	10.3	13.2
JPN	10.7	11.3	9.6	0.4	0.6	0.6	-11.3	-8.7	-5.9	0.6	0.7	0.7	6.2	8.3	10.7
POL	12.0	10.2	11.2	0.4	0.6	0.6	-10.5	-6.9	-4.0	0.6	0.7	0.7	11.2	14.5	18.3
RUS	22.7	14.1	15.9	0.4	0.6	0.6	-8.2	-4.6	-2.9	0.6	0.7	0.7	15.8	21.0	27.8
USA	25.4	25.7	24.0	0.4	0.6	0.6	-14.8	-11.2	-7.5	0.6	0.7	0.7	13.6	17.5	21.4
Annex I	16.5	14.9	14.2	0.4	0.6	0.6	-9.2	-7.6	-5.3	0.6	0.7	0.7	10.9	13.9	17.6
BRZ	4.5	5.3	5.9	0.4	0.6	0.6	-1.2	-0.6	0.1	0.6	0.7	0.7	5.7	7.2	9.5
CHN	3.1	3.6	6.5	0.4	0.6	0.6	2.4	2.7	3.4	0.6	0.7	0.7	7.5	10.5	16.2
IND	1.3	1.5	2.0	0.6	0.7	1.1	1.6	2.3	2.9	0.6	0.7	0.7	3.5	5.4	8.4
MEX	5.5	5.7	6.9	0.4	0.6	0.6	-1.5	-1.2	-0.2	0.6	0.7	0.7	7.4	9.8	13.7
ZAF	9.6	8.9	9.2	0.4	0.6	0.6	1.9	3.5	4.5	0.6	0.7	0.7	8.7	14.3	20.0
LDCs	1.3	1.3	1.5	0.8	1.0	1.0	2.1	2.8	3.4	0.6	0.7	0.7	2.5	3.6	4.6
Non-Annex I	2.8	3.1	4.3	0.6	0.7	0.8	1.9	2.3	2.7	0.6	0.7	0.7	5.6	7.1	10.5

Table 5. Cumulative emission allowances (1990 – 2020 and 1990 – 2050) per capita (in 2020 and 2050) under CDC, C&C and GDRs excluding LUCF

	Population million people			Cumulative emissions Mt CO2 eq./cap		CDC Mt CO2eq./cap 1990-2020			GDRs Mt CO2eq./cap 1990-2020			C&C 2050 convergence Mt CO2eq./cap 1990-2020		
Year	2000	2010	2020	1990-2000	1990-2010									
Country group	Median	Median	Median	Median	Median	Min	Median	Max	Min	Median	Max	Min	Median	Max
World	6033	6873	7854	53	101	136	156	172	136	138	139	136	156	172
EU27	482	499	512	115	219	298	327	348	290	292	294	301	334	358
GER	82	84	86	139	261	350	384	407	334	335	340	353	389	416
UK	60	61	63	128	239	324	356	378	302	303	307	327	362	388
JPN	127	130	132	109	214	290	317	336	276	278	280	293	324	348
POL	38	38	39	114	217	307	338	360	309	315	322	310	345	371
RUS	146	145	152	168	317	427	469	498	428	438	442	428	473	506
USA	282	310	338	237	449	597	663	709	553	556	566	592	654	700
Annex I	1248	1313	1392	150	285	382	422	449	370	371	375	382	423	454
BRZ	174	203	237	44	87	118	134	146	120	121	123	119	138	153
CHN	1263	1368	1511	34	77	117	134	146	126	132	133	120	140	156
IND	1016	1186	1375	13	26	41	52	65	40	43	44	40	50	60
MEX	98	111	130	50	100	136	155	170	138	141	142	137	158	175
ZAF	44	52	67	81	149	183	210	230	183	188	189	180	205	225
LDCs	647	815	994	11	21	32	41	50	32	33	33	33	42	51
Non-Annex I	4734	5499	6390	27	56	82	97	111	85	87	88	82	97	111

	Population million people			Cumulative emissions Mt CO2 eq./cap		CDC Mt CO2eq./cap 1990-2050			GDRs Mt CO2eq./cap 1990-2050			C&C 2050 convergence Mt CO2eq./cap 1990-2050		
	2000	2010	2050	1990-2000	1990-2010									
	Median	Median	Median	Median	Median	Min	Median	Max	Min	Median	Max	Min	Median	Max
World	6033	6873	10823	53	101	201	205	208	202	204	205	201	204	205
EU27	482	499	537	115	219	367	370	372	126	157	215	392	396	398
GER	82	84	91	139	261	428	430	433	129	156	227	452	456	457
UK	60	61	67	128	239	399	402	404	81	112	185	423	427	428
JPN	127	130	134	109	214	355	357	359	95	119	172	380	384	384
POL	38	38	38	114	217	380	383	385	266	306	343	406	411	411
RUS	146	145	183	168	317	523	525	527	450	483	527	549	556	563
USA	282	310	419	237	449	746	749	752	291	331	453	759	766	768
Annex I	1248	1313	1637	150	285	474	476	479	231	266	319	495	499	501
BRZ	174	203	350	44	87	163	165	168	150	163	180	181	184	185
CHN	1263	1368	1976	34	77	161	163	165	239	273	279	183	188	189
IND	1016	1186	1871	13	26	104	108	111	114	127	142	82	86	87
MEX	98	111	193	50	100	187	190	192	175	182	200	205	208	209
ZAF	44	52	106	81	149	253	256	260	302	347	354	258	264	264
LDCs	647	815	1495	11	21	85	90	94	105	118	128	74	77	78
Non-Annex I	4734	5499	9071	27	56	141	144	148	176	189	198	137	139	140

Note: Cumulative emissions are divided by the absolute number of people in that year. E.g. for 2020 Cumulative emission from 1990 to 2020 are divided by the population of 2020.

Table 6. Cumulative emission allowances from 1990 to 2020 and 2050 under CDC, C&C and GDRs excluding LUCF

Year	Cumulative emissions Gt CO2 eq. 1990-2000	Cumulative emissions Gt CO2 eq. 1990-2010	CDC Gt CO2 eq. 1990-2020			GDRs Gt CO2 eq. 1990-2020			C&C 2050 convergence Gt CO2 eq. 1990-2020		
Country group	Median	Median	Min	Median	Max	Min	Median	Max	Min	Median	Max
World total	319	692	1068	1081	1089	1070	1083	1092	1068	1081	1089
Figure 02 EU27	55	109	153	154	154	149	150	150	154	155	155
Figure 04 GER	11	22	30	30	30	29	29	29	30	30	31
Figure 05 UK	8	15	21	21	21	19	19	19	21	21	21
Figure 07 JPN	14	28	38	38	38	36	37	37	39	39	39
Poland	4	8	12	12	12	12	12	12	12	12	12
EVOC 05 RUS	25	46	65	66	66	65	67	67	65	66	66
Figure 01 USA	67	139	202	204	205	187	188	191	200	202	203
UNFCCC Annex I	187	375	532	535	536	515	517	521	532	535	538
EVOC 12 BRZ	8	18	28	28	28	28	29	29	28	29	29
EVOC 24 CHN	42	106	177	182	183	190	199	201	181	186	187
EVOC 25 IND	13	31	56	60	61	56	59	61	55	58	58
EVOC 13 MEX	5	11	18	18	18	18	18	19	18	18	18
EVOC 17 ZAF	4	8	12	12	12	12	13	13	12	12	12
Least Developed Countries	7	17	32	33	33	32	33	33	32	33	33
UNFCCC Non Annex I	129	311	525	536	542	541	556	564	525	535	540

	Cumulative emissions Gt CO2 eq. 1990-2000	Cumulative emissions Gt CO2 eq. 1990-2010	CDC Gt CO2 eq. 1990-2050			GDRs Gt CO2 eq. 1990-2050			C&C 2050 convergence Gt CO2 eq. 1990-2050		
	Median	Median	Min	Median	Max	Min	Median	Max	Min	Median	Max
World total	319	692	1580	1599	1607	1583	1602	1610	1580	1599	1607
Figure 02 EU27	55	109	188	191	192	65	81	110	201	203	204
Figure 04 GER	11	22	37	37	37	11	13	20	39	39	39
Figure 05 UK	8	15	25	26	26	5	7	12	27	27	27
Figure 07 JPN	14	28	47	47	48	13	16	23	50	50	51
Poland	4	8	15	15	15	10	12	13	16	16	16
EVOC 05 RUS	25	46	79	81	82	68	73	80	83	85	86
Figure 01 USA	67	139	252	256	257	99	112	153	257	259	260
UNFCCC Annex I	187	375	659	669	673	321	370	443	689	694	698
EVOC 12 BRZ	8	18	39	40	40	36	39	43	43	44	44
EVOC 24 CHN	42	106	243	255	256	360	412	421	276	284	286
EVOC 25 IND	13	31	143	150	154	156	174	195	113	118	119
EVOC 13 MEX	5	11	24	25	25	23	24	26	27	27	27
EVOC 17 ZAF	4	8	17	17	17	20	23	24	17	18	18
Least Developed Countries	7	17	84	90	92	105	117	127	74	76	77
UNFCCC Non Annex I	129	311	898	917	919	1123	1207	1268	873	890	893

Table 7. Cumulative emission allowances from 2010 to 2020 and 2050 under CDC, C&C and GDRs excluding LUCF

Year	Cumulative emissions Gt CO2 eq. 1990-2000	Cumulative emissions Gt CO2 eq. 1990-2010	CDC Gt CO2 eq. 2010-2020			GDRs Gt CO2 eq. 2010-2020			C&C 2050 convergence Gt CO2 eq. 2010-2020		
Country group	Median	Median	Min	Median	Max	Min	Median	Max	Min	Median	Max
World total	319	692	376	387	395	377	388	396	376	389	397
Figure 02 EU27	55	109	43	44	44	38	39	40	45	45	46
Figure 04 GER	11	22	8	8	8	7	7	7	9	9	9
Figure 05 UK	8	15	6	6	6	4	4	5	6	6	6
Figure 07 JPN	14	28	10	11	11	8	8	9	11	11	11
Poland	4	8	4	4	4	4	4	4	4	4	4
EVOC 05 RUS	25	46	19	19	20	19	20	21	19	20	20
Figure 01 USA	67	139	63	64	65	48	48	52	61	63	63
UNFCCC Annex I	187	375	157	160	161	139	140	144	157	161	163
EVOC 12 BRZ	8	18	10	10	11	11	11	11	10	11	11
EVOC 24 CHN	42	106	71	76	76	84	92	94	75	80	81
EVOC 25 IND	13	31	25	29	30	25	28	29	25	27	27
EVOC 13 MEX	5	11	7	7	7	7	7	7	7	7	7
EVOC 17 ZAF	4	8	4	4	5	4	5	5	4	4	4
Least Developed Countries	7	17	14	15	16	14	15	16	15	15	16
UNFCCC Non Annex I	129	311	214	224	229	231	244	252	215	224	230

	Cumulative emissions Gt CO2 eq. 1990-2000	Cumulative emissions Gt CO2 eq. 1990-2010	CDC Gt CO2 eq. 2010-2050			GDRs Gt CO2 eq. 2010-2050			C&C 2050 convergence Gt CO2 eq. 2010-2050		
	Median	Median	Min	Median	Max	Min	Median	Max	Min	Median	Max
World total	319	692	888	905	913	889	906	914	888	907	915
Figure 02 EU27	55	109	79	81	83	-45	-30	0	91	94	94
Figure 04 GER	11	22	15	15	16	-11	-9	-2	17	17	18
Figure 05 UK	8	15	11	11	11	-10	-8	-3	12	12	12
Figure 07 JPN	14	28	19	20	20	-15	-12	-5	22	23	23
Poland	4	8	6	7	7	2	3	5	7	8	8
EVOC 05 RUS	25	46	33	35	36	22	27	34	37	38	39
Figure 01 USA	67	139	113	117	117	-41	-27	13	117	120	120
UNFCCC Annex I	187	375	284	294	298	-55	-7	66	314	319	323
EVOC 12 BRZ	8	18	21	22	22	18	21	25	25	26	26
EVOC 24 CHN	42	106	137	149	149	254	305	314	170	178	180
EVOC 25 IND	13	31	112	119	123	126	143	164	82	87	88
EVOC 13 MEX	5	11	13	14	14	12	12	15	16	16	16
EVOC 17 ZAF	4	8	9	9	9	12	15	16	9	10	10
Least Developed Countries	7	17	67	73	74	87	99	110	56	59	60
UNFCCC Non Annex I	129	311	587	605	607	813	895	955	562	579	582

Appendix C Comparison of data from EcoEquity and EVOC

original data
roughly calculated

	China	India	World
Development threshold			
EcoEquity			7,500
Ecofys			7,500
GDP, 2005, PPP, billion $			
Ecofys (ppp 2000)	5,333	2,441	55,588
Word Bank (PPP 2005) (WDI, 2008)	5,333	2,441	56,265
Word Bank	5,333	2,341	54,980
GDP, 2020, PPP, billion $			
EcoEquity	12,971	6,623	99,708
Ecofys (ppp 2000)	17,529	8,524	95,150
EcoEquity, % of global	13%	7%	100%
Ecofys, % of global	18%	9%	100%
GDP per capita, 2010, PPP			
EcoEquity	5,899	2,818	9,929
Ecofys (ppp 2000)	5,864	3,005	10,095
EcoEquity, % change from global average	-41%	-72%	0%
Ecofys, % change from global average	-42%	-70%	0%
Population (% of global), 2010			
EcoEquity	19.7%	17.2%	100%
Ecofys	19.7%	17.3%	100%
RCI (share of global)			
EcoEquity (2010)	5.5%	0.5%	100%
Ecofys (2010)			
EcoEquity (2030)	15.2%	2.3%	100%
Ecofys (2030)	14.5%	3.5%	100%
Emissions, roughly, GtCO2			
IEA 2000	3	1	23
EcoEquity 2000	3	1	29
EcoEquity 2030, BAU	12	3	50
EcoEquity 2030, GDRs	7	3	17
Emissions, MtCO2e			
Ecofys 2000	5	1	32
Ecofys 2030, BAU (median)	14	5	63
Ecofys 2030, GDRs (median)	8	4	22
Emissions, growth rate 2000-2030			
EcoEquity, BAU	304%	520%	69%
Ecofys, BAU	205%	313%	98%
EcoEquity, GDRs	129%	373%	-41%
Ecofys, GDRs	77%	216%	-31%
Emissions, change to BAU, 2030			
EcoEquity, %	-43%	-24%	-65%
Ecofys, %	-42%	-24%	-65%
EcoEquity, GtCO2	5	1	32
Ecofys, GtCO2e	6	1	41
Gases included			
EcoEquity:	CO2 only		
Ecofys:	CO2eq (CO2, CH4, N2O, PFCs, HFCs, SF6)		

Document:	WWF carbon budget 2009-02-04.doc	
Last saved:	October 1, 2009	Sara Moltmann
Author:	SMo	

CAPCOA

CALIFORNIA AIR POLLUTION CONTROL OFFICERS ASSOCIATION

CEQA & Climate Change

Evaluating and Addressing Greenhouse Gas Emissions from Projects Subject to the California Environmental Quality Act

January 2008

Disclaimer

The California Air Pollution Control Officers Association (CAPCOA) has prepared this white paper consideration of evaluating and addressing greenhouse gas emissions under the California Environmental Quality Act (CEQA) to provide a common platform of information and tools to support local governments.

This paper is intended as a resource, not a guidance document. It is not intended, and should not be interpreted, to dictate the manner in which an air district or lead agency chooses to address greenhouse gas emissions in the context of its review of projects under CEQA.

This paper has been prepared at a time when California law has been recently amended by the Global Warming Solutions Act of 2006 (AB 32), and the full programmatic implications of this new law are not yet fully understood. There is also pending litigation in various state and federal courts pertaining to the issue of greenhouse gas emissions. Further, there is active federal legislation on the subject of climate change, and international agreements are being negotiated. Many legal and policy questions remain unsettled, including the requirements of CEQA in the context of greenhouse gas emissions. This paper is provided as a resource for local policy and decision makers to enable them to make the best decisions they can in the face of incomplete information during a period of change.

Finally, this white paper reviews requirements and discusses policy options, but it is not intended to provide legal advice and should not be construed as such. Questions of legal interpretation, particularly in the context of CEQA and other laws, or requests for advice should be directed to the agency's legal counsel.

Acknowledgements

This white paper benefited from the hard work and creative insights of many people. CAPCOA appreciates the efforts of all who contributed their time and energy to the project. In particular, the Association thanks the following individuals:

Principal Authors

Greg Tholen, BAAQMD
Dave Vintze, BAAQMD
Jean Getchell, MBUAPCD
Matt Jones, YSAQMD
Larry Robinson, SMAQMD
Ron Tan, SBCAPCD

Editor

Barbara Lee, NSAPCD

Reviewers

CAPCOA Climate Protection Committee

Barbara Lee (NSCAPCD), Chair

Larry Allen, SLOCPCD
Bobbie Bratz, SBAPCD
Karen Brooks, SLOCAPCD
Chris Brown, MCAQMD
Tom Christofk, PCAPCD
Jorge DeGuzman, SMAQMD
Mat Ehrhardt, YSAQMD
Jean Getchell, MBUAPCD
Larry Greene, SMAQMD
Henry Hilken, BAAQMD
Alan Hobbs, PCAPCD
Jim Jester, SMAQMD
Dave Jones, KCAPCD
Tom Jordan, SJVUAPCD
Tom Murphy, SBAPCD
Don Price, VCAPCD
Jean Roggenkamp, BAAQMD
Ana Sandoval, BAAQMD
Amy Taketomo, MBUAPCD
Tim Taylor, SMAQMD
Mike Villegas, VCAPCD
David Vintze, BAAQMD
Dave Warner, SJVUAPCD
Jill Whynot, SCAQMD
John Yu, CAPCOA
Mel Zeldin, CAPCOA

CAPCOA Planning Managers: CEQA & Climate Change Subcommittee

Dave Vintze (BAAQMD), Chair
Greg Tholen (BAAQMD), Project Manager

Charles Anderson, SMAQMD
Aeron Arlin Genet, SLOCAPCD
Jean Getchell, MBUAPCD
Melissa Guise, SLOCAPCD
Matt Jones, YSAQMD
Barbara Lee, NSCAPCD
Ryan Murano, NSAQMD
Tom Murphy, SBCAPCD
Susan Nakamura, SCAQMD
Larry Robinson, SMAQMD
Jean Roggenkamp, BAAQMD
Ana Sandoval, BAAQMD
Ron Tan, SBCAPCD
Brigette Tollstrup, SMAQMD
Jill Whynot, SCAQMD

External Reviewers

James Goldstene, CARB
Annmarie Mora, CARB
Terri Roberts, OPR

Proofing & Layout

Jake Toolson, CAPCOA
John Yu, CAPCOA

Contract Support

Jones & Stokes, Sacramento, CA *(analysis of non-zero threshold approaches)*
EDAW, Inc., Sacramento, CA *(review of analytical methods and mitigation strategies)*.

Table of Contents

Executive Summary 1

Chapter

1. Introduction 5
2. Air Districts and CEQA Thresholds 11
3. Consideration of Fundamental Issues 13
4. Consideration of a Statewide Threshold 21
5. CEQA with No GHG Thresholds 23
6. CEQA With GHG Threshold of Zero 27
7. CEQA With Non-Zero Thresholds 31
   - Approach 1: Statute and Executive Order Approach 32
   - Approach 2: Tiered Approach 36
8. Analytical Methodologies for GHG 59
9. Mitigation Strategies for GHG 79
10. Examples of Other Approaches 85

Appendix A – Relevant Citations

Appendix B – Mitigation Measure Summary

Appendix C – Rule and Regulation Summary

List of Figures

Figure 1 – Climate Change Significance Criteria Flow Chart 38

List of Tables

Table 1 – Analysis of GHG Emissions from Stationary Combustion Equipment Permits 18
Table 2 – Approach 2 Tiering Options 41
Table 3 – Comparison of Approach 2 Tiered Threshold Options 49
Table 4 – Non-Zero Threshold Evaluation Matrix – Approach 1 56
Table 5 – Non-Zero Threshold Evaluation Matrix – Approach 2 57
Table 6 – Residential Project Example GHG Emissions Estimates 62
Table 7 – Commercial Project Example GHG Emissions Estimates 63
Table 8 – Specific Plan Example GHG Emissions Estimates 64
Table 9 – General Plan Example GHG Emissions Estimates.....68
Table 10 – Summary of Modeling Tools for GHG Emissions 75
Table 11 – Residential Project Example GHG Emissions Estimates with Mitigation ..81
Table 12 – Residential Projects Example Methodology and Mitigation 82
Table 13 – Commercial Projects Example Methodology and Mitigation 82
Table 14 – Specific Plans Example Methodology and Mitigation 83
Table 15 – General Plans Example Methodology and Mitigation.....83
Table 16 – Mitigation Measure Summary B-1
Table 17 – General Planning Level Mitigation Strategies Summary B-35
Table 18 – Rule and Regulation Summary C-1

List of Acronyms and Abbreviations

Acronym/ Abbreviation	Meaning
AB 32	Assembly Bill 32 Global Warming Solutions Act of 2006
AG	Attorney General
ARB	Air Resources Board
ASTM	American Society of Testing and Material
BAAQMD	Bay Area Air Quality Management District
BAU	Business as Usual
BEES	Building for Environmental and Economic Sustainability
Calfire	California Fire
Caltrans	California Department of Transportation
CAP	Criteria Air Pollutants
CAPCOA	California Air Pollution Control Officers Association
CARB	California Air Resource Board
CAT	Climate Action Team
CCAP	Center for Clean Air Policy
CCAR	California Climate Action Registry
CDFA	California Department of Food and Agriculture
CEC	California Energy Commission
CEQA	California Environmental Quality Act
CF	Connectivity Factor
CH_4	Methane
CIWMB	California Integrated Waste Management Board
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CNG	Compressed Natural Gas
CPUC	California Public Utilities Commission
CUFR	California Urban Forestry
DGS	Department of General Services
DOE	U.S. Department of Energy
DOF	Department of Finance
DPF	Diesel Particulate Filter
DWR	Department of Water Resources
E85	85% Ethanol
EEA	Massachusetts Executive Office of Energy and Environmental Affairs
EERE	Energy Efficiency and Renewable Energy
EIR	Environmental Impact Report
EOE	Encyclopedia of Earth
EPA	U.S. Environmental Protection Agency
ETC	Edmonton Trolley Coalition
EV	Electric Vehicles
FAR	Floor Area Ratio

GHG	Greenhouse Gas
GGEP	Greenhouse Gas Emissions Policy
GGRP	Greenhouse Gas Reduction Plan
GP	General Plan
GWP	Global Warming Potential
IGCC	Integrated Gasification Combined Cycle
IOU	Investor Owned Utility
IPCC	International Panel on Climate Change
IT	Information Technology
ITE	Institute of Transportation Engineers
J&S	Jones & Stokes
km	Kilometer
LandGem	Landfill Gas Emissions Model
LEED	Leadership in Energy and Environmental Design
LNG	Liquefied Natural Gas
MBUAPCD	Monterey Bay Unified Air Pollution Control District
MEPA	Massachusetts Environmental Policy Act
MND	Mitigated Negative Declaration
MMT CO_2e	Million Metric Tons Carbon Dioxide Equivalent
MW	Megawatts
N_2O	Nitrous Oxide
NACAA	National Association Clean Air Agencies
ND	Negative Declaration
NEV	Neighborhood Electric Vehicle
NIST	National Institute of Standards and Technology
NO_X	Oxides of Nitrogen
NREL	National Renewable Energy Laboratory
NSCAPCD	Northern Sonoma County Air Pollution Control District
NSR	New Source Review
OPR	State Office of Planning and Research
PFC	Perfluorocarbon
PG&E	Pacific Gas & Electric
POU	Publicly Owned Utility
PM	Particulate Mater
RoadMod	Road Construction Emissions Model
ROG	Reactive Organic Gas
RPS	Renewable Portfolio Standards
RTP	Regional Transportation Plan
S-3-05	Executive Order S-3-05
SB	Senate Bill
SBCAPCD	Santa Barbara County Air Pollution Control District
SCAQMD	South Coast Air Quality Management District
SCM	Sustainable Communities Model
SIP	State Implementation Plan
SJVAPCD	San Joaquin Valley Unified Air Pollution Control District
SLOCAPCD	San Luis Obispo County Air Pollution Control District

SMAQMD	Sacramento Metropolitan Air Quality Management District
SMUD	Sacramento Municipal Utilities District
SO_X	Sulfur Oxides
SP	Service Population
SRI	Solar Reflectance Index
SWP	State Water Project
TAC	Toxic Air Contaminants
TBD	To Be Determined
TDM	Transportation Demand Management
TMA	Transportation Management Association
THC	Total Hydrocarbon
UC	University of California
ULEV	Ultra Low Emission Vehicle
UNFCCC	United Nations Framework Convention on Climate Change
URBEMIS	Urban Emissions Model
USGBC	U.S. Green Building Council
VMT	Vehicle Miles Traveled
VTPI	Victoria Transit Policy
YSAQMD	Yolo-Solano Air Quality Management District

Introduction

The California Environmental Quality Act (CEQA) requires that public agencies refrain from approving projects with significant adverse environmental impacts if there are feasible alternatives or mitigation measures that can substantially reduce or avoid those impacts. There is growing concern about greenhouse gas emissions[1] (GHG) and recognition of their significant adverse impacts on the world's climate and on our environment. In its most recent reports, the International Panel on Climate Change (IPCC) has called the evidence for this "unequivocal." In California, the passage of the Global Warming Solutions Act of 2006 (AB 32) recognizes the serious threat to the "economic well-being, public health, natural resources, and the environment of California" resulting from global warming. In light of our current understanding of these impacts, public agencies approving projects subject to the CEQA are facing increasing pressure to identify and address potential significant impacts due to GHG emissions. Entities acting as lead agencies in the CEQA process are looking for guidance on how to adequately address the potential climate change impacts in meeting their CEQA obligations.

Air districts have traditionally provided guidance to local lead agencies on evaluating and addressing air pollution impacts from projects subject to CEQA. Recognizing the need for a common platform of information and tools to support decision makers as they establish policies and programs for GHG and CEQA, the California Air Pollution Control Officers Association has prepared a white paper reviewing policy choices, analytical tools, and mitigation strategies.

This paper is intended to serve as a resource for public agencies as they establish agency procedures for reviewing GHG emissions from projects under CEQA. It considers the application of thresholds and offers three alternative programmatic approaches toward

[1] Throughout this paper GHG, CO_2, CO_2e, are used interchangeably and refer generally to greenhouse gases but do not necessarily include all greenhouse gases unless otherwise specified.

determining whether GHG emissions are significant. The paper also evaluates tools and methodologies for estimating impacts, and summarizes mitigation measures. It has been prepared with the understanding that the programs, regulations, policies, and procedures established by the California Air Resources Board (CARB) and other agencies to reduce GHG emissions may ultimately result in a different approach under CEQA than the strategies considered here. The paper is intended to provide a common platform for public agencies to ensure that GHG emissions are appropriately considered and addressed under CEQA while those programs are being developed.

Examples of Other Approaches

Many states, counties, and cities have developed policies and regulations concerning greenhouse gas emissions that seek to require or promote reductions in GHG emissions through standards for vehicle emissions, fuels, electricity production/renewables, building efficiency, and other means. A few have developed guidance and are currently considering formally requiring or recommending the analysis of greenhouse gas emissions for development projects during their associated environmental processes. Key work in this area includes:

- Massachusetts Office of Energy and Environmental Affairs Greenhouse Gas Emissions Policy;
- King County, Washington, Executive Order on the Evaluation of Climate Change Impacts through the State Environmental Policy Act;
- Sacramento AQMD interim policy on addressing climate change in CEQA documents; and
- Mendocino AQMD updated guidelines for use during preparation of air quality impacts in Environmental Impact Reports (EIRs) or mitigated negative declarations.

The following paper evaluates options for lead agencies to ensure that GHG emissions are appropriately addressed as part of analyses under CEQA. It considers the use of significance thresholds, tools and methodologies for analyzing GHG emissions, and measures and strategies to avoid, reduce, or mitigate impacts.

Greenhouse Gas Significance Criteria

This white paper discusses three basic options air districts and lead agencies can pursue when contemplating the issues of CEQA thresholds for greenhouse gas emissions. This paper explores each path and discusses the benefits and disbenefits of each. The three basic paths are:

- No significance threshold for GHG emissions;

- GHG emissions threshold set at zero; or
- GHG threshold set at a non-zero level.

Each has inherent advantages and disadvantages. Air districts and lead agencies may believe the state or national government should take the lead in identifying significance thresholds to address this global impact. Alternatively, the agency may believe it is premature or speculative to determine a clear level at which a threshold should be set. On the other hand, air districts or lead agencies may believe that every GHG emission should be scrutinized and mitigated or offset due to the cumulative nature of this impact. Setting the threshold at zero will place all discretionary projects under the CEQA microscope. Finally, an air district or lead agency may believe that some projects will not benefit from a full environmental impact report (EIR), and may believe a threshold at some level above zero is needed.

This paper explores the basis and implications of setting no threshold, setting a threshold at zero and two primary approaches for those who may choose to consider a non-zero threshold. The first approach is grounded in statute (AB 32) and executive order (EO S-3-05) and explores four possible options under this scenario. The options under this approach are variations of ways to achieve the 2020 goals of AB 32 from new development, which is estimated to be about a 30 percent reduction from business as usual.

The second approach explores a tiered threshold option. Within this option, seven variations are discussed. The concepts explored here offer both quantitative and qualitative approaches to setting a threshold as well as different metrics by which tier cut-points can be set. Variations range from setting the first tier cut-point at zero to second-tier cut-points set at defined emission levels or based on the size of a project. It should be noted that some applications of the tiered threshold approach may require inclusion in a General Plan or adoption of enabling regulations or ordinances to render them fully effective and enforceable.

Greenhouse Gas Analytical Methodologies

The white paper evaluates various analytical methods and modeling tools that can be applied to estimate the greenhouse gas emissions from different project types subject to CEQA. In addition, the suitability of the methods and tools to characterize accurately a project's emissions is discussed and the paper provides recommendations for the most appropriate methodologies and tools currently available.

The suggested methodologies are applied to residential, commercial, specific plan and general plan scenarios where GHG emissions are estimated for each example. This chapter also discusses estimating emissions from solid waste facilities, a wastewater treatment plant, construction, and air district rules and plans.

Another methodology, a service population metric, that would measure a project's overall GHG efficiency to determine if a project is more efficient than the existing statewide average for per capita GHG emissions is explored. This methodology may be more directly correlated to a project's ability to help achieve objectives outlined in AB 32, although it relies on establishment of an efficiency-based significance threshold. The subcommittee believes this methodology may eventually be appropriate to evaluate the long-term GHG emissions from a project in the context of meeting AB 32 goals. However, this methodology will need further work and is not considered viable for the interim guidance presented in this white paper.

Greenhouse Gas Mitigation Measures

Common practice in environmental protection is first to avoid, then to minimize, and finally to compensate for impacts. When an impact cannot be mitigated on-site, off-site mitigation can be effectively implemented in several resource areas, either in the form of offsetting the same impact or preserving the resource elsewhere in the region.

This white paper describes and evaluates currently available mitigation measures based on their economic, technological and logistical feasibility, and emission reduction effectiveness. The potential for secondary impacts to air quality are also identified for each measure. A summary of current rules and regulations affecting greenhouse gas emissions and climate change is also provided.

Reductions from transportation related measures (e.g., bicycle, pedestrian, transit, and parking) are explored as a single comprehensive approach to land use. Design measures that focus on enhancing alternative transportation are discussed. Mitigation measures are identified for transportation, land use/building design, mixed-use development, energy efficiency, education/social awareness and construction.

Purpose

CEQA requires the avoidance or mitigation of significant adverse environmental impacts where there are feasible alternatives available. The contribution of GHG to climate change has been documented in the scientific community. The California Global Warming Solutions Act of 2006 (AB 32) mandates significant reductions in greenhouse gases (GHG); passage of that law has highlighted the need to consider the impacts of GHG emissions from projects that fall under the jurisdiction of the California Environmental Quality Act (CEQA). Because we have only recently come to fully recognize the potential for significant environmental impacts from GHG, most public agencies have not yet established policies and procedures to consider them under CEQA. As a result, there is great need for information and other resources to assist public agencies as they develop their programs.

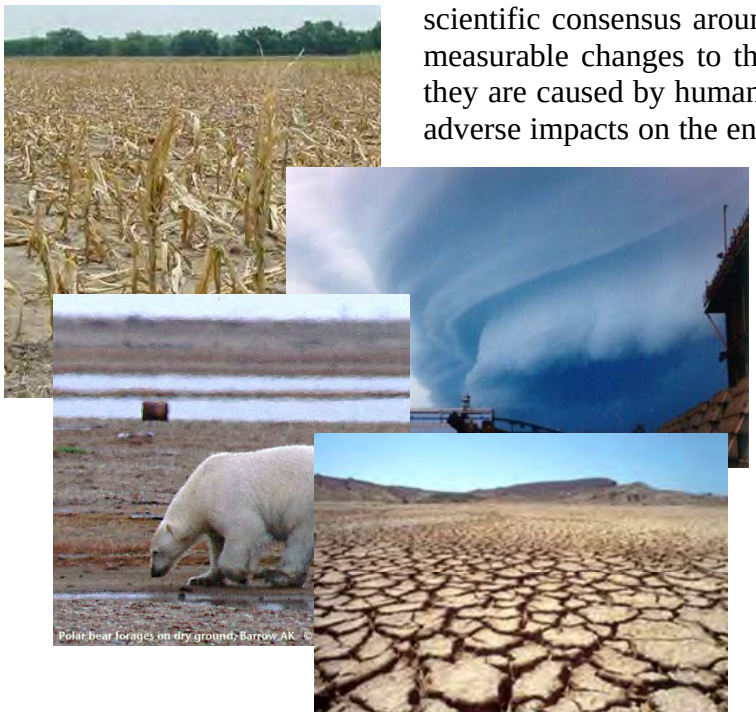
Air districts have historically provided guidance to local governments on the evaluation of air pollutants under CEQA. As local concern about climate change and GHG has increased, local governments have requested guidance on incorporating analysis of these impacts into local CEQA review. The California Air Pollution Control Officers Association (CAPCOA), in coordination with the CARB, the Governor's Office of Planning and Research (OPR) and two environmental consulting firms, has harnessed the collective expertise to evaluate approaches to analyzing GHG in CEQA. The purpose of this white paper is to provide a common platform of information and tools to address climate change in CEQA analyses, including the evaluation and mitigation of GHG emissions from proposed projects and identifying significance threshold options.

CEQA requires public agencies to ensure that potentially significant adverse environmental effects of discretionary projects are fully characterized, and avoided or mitigated where there are feasible alternatives to do so. Lead agencies have struggled with how best to identify and characterize the magnitude of the adverse effects that individual projects have on the global-scale phenomenon of climate change, even more so since Governor Schwarzenegger signed Executive Order S-3-05 and the state Legislature enacted The Global Warming Solutions Act of 2006 (AB 32). There is now a resounding call to establish procedures to analyze and mitigate greenhouse gas (GHG) emissions. The lack of established thresholds does not relieve lead agencies of their responsibility to analyze and mitigate significant impacts, so many of these agencies are seeking guidance from state and local air quality agencies. This white paper addresses issues inherent in establishing CEQA thresholds, evaluates tools, catalogues mitigation measures and provides air districts and lead agencies with options for incorporating climate change into their programs.

Background

National and International Efforts

International and Federal legislation have been enacted to deal with climate change issues. The Montreal Protocol was originally signed in 1987 and substantially amended in 1990 and 1992. In 1988, the United Nations and the World Meteorological Organization established the IPCC to assess the scientific, technical and socioeconomic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts, and options for adaptation and mitigation. The most recent reports of the IPCC have emphasized the scientific consensus around the evidence that real and measurable changes to the climate are occurring, that they are caused by human activity, and that significant adverse impacts on the environment, the economy, and human health and welfare are unavoidable.



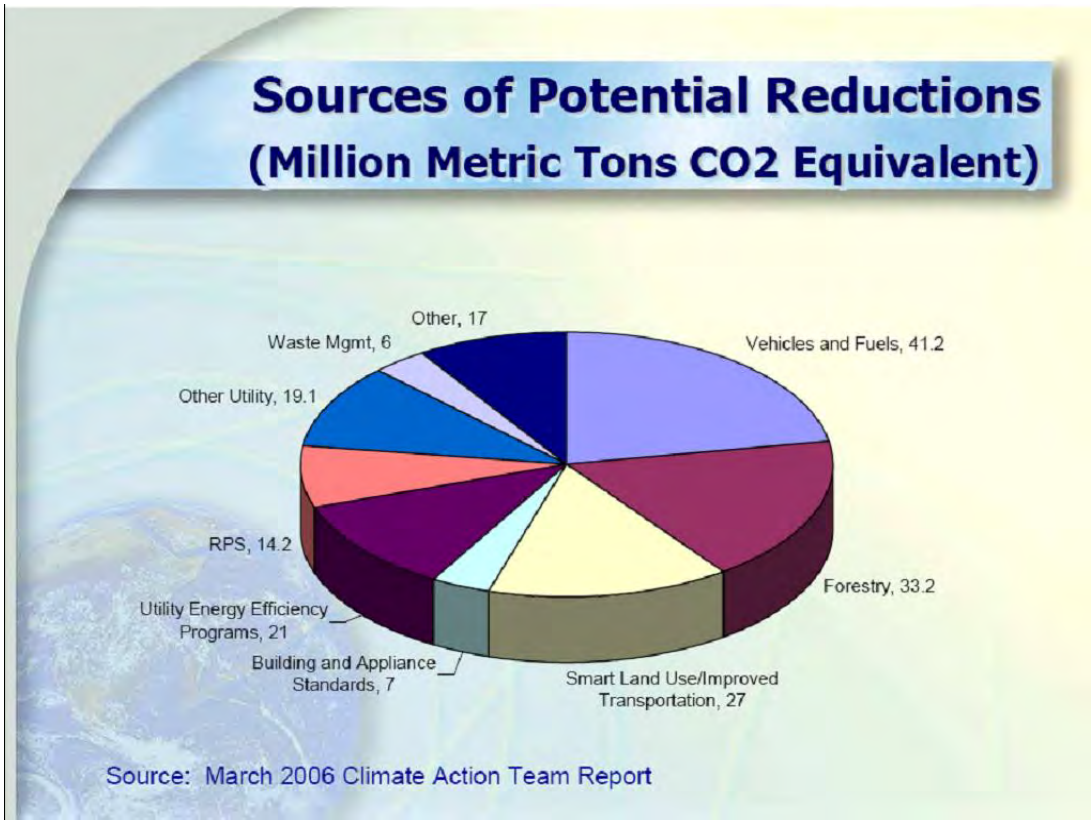
In October 1993, President Clinton announced his Climate Change Action Plan, which had a goal to return greenhouse gas emissions to 1990 levels by the year 2000. This was to be accomplished through 50 initiatives that relied on innovative voluntary partnerships between the private sector and government aimed at producing cost-effective reductions in greenhouse gas emissions. On March 21, 1994, the United States joined a number of countries around the world in signing the United Nations Framework Convention on Climate Change (UNFCCC). Under the Convention, governments agreed to gather and share information on greenhouse gas emissions, national policies, and best practices; launch national strategies for addressing greenhouse gas emissions and adapting to expected impacts, including the provision of financial and technological support to developing countries; and cooperate in preparing for adaptation to the impacts of climate change.

These efforts have been largely policy oriented. In addition to the national and international efforts described above, many local jurisdictions have adopted climate change policies and programs. However, thus far little has been done to assess the significance of the affects new development projects may have on climate change.

Executive Order S-3-05

On June 1, 2005, Governor Schwarzenegger issued Executive Order S-3-05 (S-3-05). It included the following GHG emission reduction targets: by 2010, reduce GHG emissions to 2000 levels; by 2020, reduce GHG emissions to 1990 levels; by 2050, reduce GHG emissions to 80 percent below 1990 levels. To meet the targets, the Governor directed the Secretary of the California Environmental Protection Agency to coordinate with the Secretary of the Business, Transportation and Housing Agency, Secretary of the Department of Food and Agriculture, Secretary of the Resources Agency, Chairperson of the CARB, Chairperson of the Energy Commission and President of the Public Utilities Commission on development of a Climate Action Plan.

The Secretary of CalEPA leads a Climate Action Team (CAT) made up of representatives from the agencies listed above to implement global warming emission reduction programs identified in the Climate Action Plan and report on the progress made toward meeting the statewide greenhouse gas targets that were established in the Executive Order.



SOURCE: ARB 2007

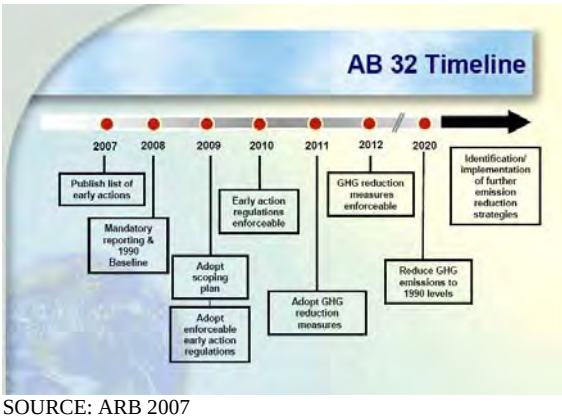
In accord with the requirements of the Executive Order, the first report to the Governor and the Legislature was released in March 2006 and will be issued bi-annually thereafter. The CAT Report to the Governor contains recommendations and strategies to help ensure the targets in Executive Order S-3-05 are met.

California Global Warming Solutions Act of 2006 (AB 32)

In 2006, the California State Legislature adopted the California Global Warming Solutions Act of 2006. AB 32 establishes a cap on statewide greenhouse gas emissions and sets forth the regulatory framework to achieve the corresponding reduction in statewide emissions levels. AB 32 charges the California Air Resources Board (CARB), the state agency charged with regulating statewide air quality, with implementation of the act. Under AB 32, greenhouse gases are defined as: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.

The regulatory steps laid out in AB 32 require CARB to: adopt early action measures to reduce GHGs; to establish a statewide greenhouse gas emissions cap for 2020 based on 1990 emissions; to adopt mandatory reporting rules for significant source of greenhouse gases; and to adopt a scoping plan indicating how emission reductions will be achieved via regulations, market mechanisms and other actions; and to adopt the regulations needed to achieve the maximum technologically feasible and cost-effective reductions in greenhouse gases.

AB 32 requires that by January 1, 2008, the State Board shall determine what the statewide greenhouse gas emissions inventory was in 1990, and approve a statewide greenhouse gas emissions limit that is equivalent to that level, to be achieved by 2020. While the level of 1990 GHG emissions has not yet been approved, CARB's most recent emission inventory indicates that California had annual emissions of 436 million metric tons of carbon dioxide equivalent (MMT CO_2e) in 1990 and 497 MMT CO_2e in 2004.



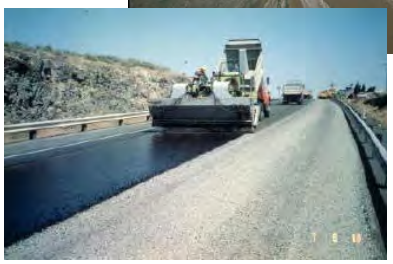
SOURCE: ARB 2007

The regulatory timeline laid out in AB 32 requires that by July 1, 2007, CARB adopt a list of discrete early action measures, or regulations, to be adopted and implemented by January 1, 2010. These actions will form part of the State's comprehensive plan for achieving greenhouse gas emission reductions. In June 2007, CARB adopted three discrete early action measures. These three new proposed regulations meet the definition of "discrete early action greenhouse gas reduction measures," which include the following: a low carbon fuel standard; reduction of HFC-134a emissions from non-professional servicing of motor vehicle air conditioning systems; and improved landfill methane capture. CARB estimates that by 2020, the reductions from those three discrete early action measures would be approximately 13-26 MMT CO_2e.

CARB evaluated over 100 possible measures identified by the CAT for inclusion in the list of discrete early action measures. On October 25, 2007 CARB gave final approval to the list of Early Action Measures, which includes nine discrete measures and 35

additional measures, all of which are to be enforceable by January 1, 2010. AB 32 requires that by January 1, 2009, CARB adopt a scoping plan indicating how emission reductions will be achieved via regulations, market mechanisms and other actions.

Senate Bill 97



Senate Bill (SB) 97, signed in August 2007, acknowledges that climate change is an important environmental issue that requires analysis under CEQA. This bill directs the OPR to prepare, develop, and transmit to the Resources Agency guidelines for the feasible mitigation of GHG emissions or the effects of GHG emissions, by July 1, 2009. The Resources Agency is required to certify or adopt those guidelines by January 1, 2010. This bill also protects projects funded by the Highway Safety, Traffic Reduction, Air Quality and Port Security Bond Act of 2006, or the Disaster Preparedness and Flood Protection Bond Act of 2006 (Proposition 1B or 1E) from claims of inadequate analysis of GHG as a legitimate cause of action. This latter provision will be repealed on January 1, 2010. Thus, this "protection" is highly limited to a handful of projects and for a short time period.

The Role of Air Districts in the CEQA Process

Air districts assume one of three roles in the CEQA process. They may be lead agencies when they are adopting regulations and air quality plans. In some instances, they can also be a lead agency when approving permits to construct or operate for applicants subject to district rules. However, in many cases where an air district permit is involved, another agency has broader permitting authority over the project and assumes the role of lead agency. In these situations, the air district becomes what is referred to as a responsible agency under CEQA. When CEQA documents are prepared for projects that do not involve discretionary approval of a district regulation, plan or permit, the air district may assume the role of a concerned or commenting agency. In this role, it is typical for air districts to comment on CEQA documents where there may be air quality-related adverse impacts, such as projects that may create significant contributions to existing violations of ambient standards, cause a violation of an ambient standard or create an exposure to toxic air contaminants or odors. In some cases, the air district may also act in an "advisory" capacity to a lead agency early on in its review of an application for a proposed development project.

A few air districts in California began developing significance thresholds for use in CEQA analyses in the late 1980's and early 1990's. By the mid-1990's most air districts had developed CEQA thresholds for air quality analyses. Many of the districts have included in their guidance the analysis of rule development and permits that may be subject to CEQA.

What is Not Addressed in this Paper

Impacts of Climate Change to a Project

The focus of this paper is addressing adverse impacts to climate change and the ability to meet statewide GHG reduction goals caused by proposed new land development projects. CEQA also requires an assessment of significant adverse impacts a project might cause by bringing development and people into an area affected by climate change (CEQA Guidelines §15126.2). For example, an area that experiences higher average temperatures due to climate change may expose new development to more frequent exceedances and higher levels of ozone concentrations. Alternatively, a rise in sea level brought on by climate change may inundate new development locating in a low-lying area. The methodologies, mitigation and threshold approaches discussed in this paper do not specifically address the potential adverse impacts resulting from climate change that may affect a project.

Impacts from Construction Activity

Although construction activity has been addressed in the analytical methodologies and mitigation chapters, this paper does not discuss whether any of the threshold approaches adequately addresses impacts from construction activity. More study is needed to make this assessment or to develop separate thresholds for construction activity. The focus of this paper is the long-term adverse operational impacts of land use development.

Introduction

Any analysis of environmental impacts under CEQA includes an assessment of the nature and extent of each impact expected to result from the project to determine whether the impact will be treated as significant or less than significant. CEQA gives lead agencies discretion whether to classify a particular environmental impact as significant. "The determination of whether a project may have a significant effect on the environment calls for careful judgment on the part of the public agency involved," ref: CEQA Guidelines §15064(b) ("Guidelines"). Ultimately, formulation of a standard of significance requires the lead agency to make a policy judgment about where the line should be drawn distinguishing adverse impacts it considers significant from those that are not deemed significant. This judgment must, however, be based on scientific information and other factual data to the extent possible (Guidelines §15064(b)).

CEQA does not require that agencies establish thresholds of significance. Guidelines §15064.7(a) encourages each public agency "…to develop and publish thresholds of significance that the agency uses in the determination of the significance of environmental effects. A threshold of significance is an identifiable quantitative, qualitative or performance level of a particular environmental effect, non-compliance with which means the effect will normally be determined to be significant by the agency and compliance with which normally means the effect will be determined to be less than significant."

Once such thresholds are established, an impact that complies with the applicable threshold will "normally" be found insignificant and an impact that does not comply with the applicable threshold will "normally" be found significant.

Additionally, Guidelines §15064.7(b) requires that if thresholds of significance are adopted for general use as part of the lead agency's environmental review process they must be adopted by ordinance, resolution, rule or regulation, and developed through a public review process and be supported by substantial evidence.

While many public agencies adopt regulatory standards as thresholds, the standards do not substitute for a public agency's use of careful judgment in determining significance. They also do not replace the legal standard for significance (i.e., if there is a fair argument, based on substantial evidence in light of the whole record that the project may have a significant effect, the effect should be considered significant) (Guidelines §15064(f)(1). Also see *Communities for a Better Environment v. California Resource Agency* 103 Cal. App. 4th 98 (2002)). In other words, the adoption of a regulatory standard does not create an irrebuttable presumption that impacts below the regulatory standard are less than significant.

Summary of CEQA Thresholds at Air Districts

This section briefly summarizes the evolution of air district CEQA significance thresholds. Ventura County APCD, in 1980, was the first air district in California that formally adopted CEQA significance thresholds. Their first CEQA assessment document contained impact thresholds based on project type: residential, nonresidential, and government. Then, as now, the District's primary CEQA thresholds applied only to ROG and NO_x. The 1980 Guidelines did not address other air pollutants.

Santa Barbara County APCD and the Bay Area AQMD adopted thresholds in 1985. The South Coast AQMD recommended regional air quality thresholds in 1987 for CO, SO_2, NO_2, particulates, ROG, and lead. Most of the other California air districts adopted CEQA guidance and thresholds during the 1990's. Air districts have updated their thresholds and guidelines several times since they were first published.

Originally, most districts that established CEQA thresholds focused on criteria pollutants for which the district was nonattainment and the thresholds only addressed project level impacts. Updates during the 1990's began to add additional air quality impacts such as odors, toxic air contaminants and construction. Several air districts also developed thresholds for General Plans that relied on an assessment of the plan consistency with the district's air quality plans. A consistency analysis involves comparing the project's land use to that of the general plan and the population and employment increase to the forecasts underlying the assumptions used to develop the air quality plan.

Most air district thresholds for CEQA are based on the threshold for review under the New Source Review (NSR). The NSR threshold level is set by district rule and is different depending on the nonattainment classification of the air district. Areas with a less severe classification have a higher NSR trigger level while the most polluted areas have the lowest NSR trigger level. Some districts, such as Ventura County APCD, have significantly lower CEQA thresholds that are not tied to the NSR requirements. In Ventura, one set of CEQA thresholds is 25 pounds per day for all regions of Ventura County, except the Ojai Valley. The second set of CEQA thresholds was set at 5 pounds per day for the Ojai Valley.

The Sacramento Metropolitan AQMD bases its thresholds for ozone precursors on the projected land use share of emission reductions needed for attainment. The emission reductions needed to reach attainment are based on commitments made in the state implementation plan (SIP) prepared for the federal clean air act.

CEQA Considerations in Setting Thresholds

Public agencies use significance thresholds to disclose to their constituents how they plan on evaluating and characterizing the severity of various environmental impacts that could be associated with discretionary projects that they review. Significance thresholds are also used to help identify the level of mitigation needed to reduce a potentially significant impact to a less than significant level and to determine what type of an environmental document should be prepared for a project; primarily a negative declaration, mitigated negative declaration or an environmental impact report.

While public agencies are not required to develop significance thresholds, if they decide to develop them, they are required to adopt them by ordinance, resolution, rule or regulation through a public process. A lead agency is not restrained from adopting any significance threshold it sees as appropriate, as long as it is based on substantial evidence. CEQA Guidelines §15064.7 encourages public agencies to develop and publish significance thresholds that are identifiable, quantitative, qualitative or performance level that the agency uses in the determination of the significance of environmental effects. The courts have ruled that a "threshold of significance" for a given environmental effect is simply that level at which the lead agency finds the effects of the project to be significant.

Before an agency determines its course with regard to climate change and CEQA, it must be made clear that a threshold, or the absence of one, will not relieve a lead agency from having to prepare an EIR or legal challenges to the adequacy of an analysis leading to a conclusion, or lack of a conclusion, of significance under CEQA. CEQA has generally favored the preparation of an EIR where there is any substantial evidence to support a fair argument that a significant adverse environmental impact may occur due to a proposed project. This paper explores three alternative approaches to thresholds, including a no threshold option, a zero threshold option and a non-zero threshold option.

<u>Fair Argument Considerations</u>

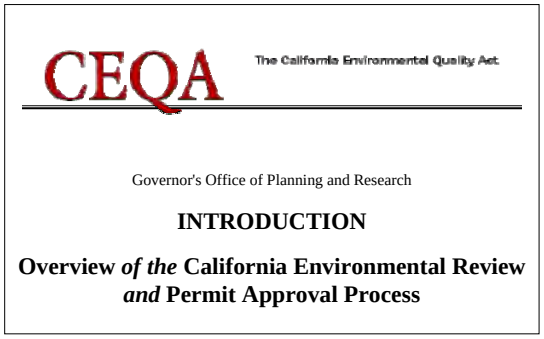
Under the CEQA fair argument standard, an EIR must be prepared whenever it can be fairly argued, based on substantial evidence in the administrative record, that a project may have a significant adverse effect on the environment. "Substantial evidence" comprises "enough relevant information and reasonable inferences from this information that a fair argument can be made to support a conclusion, even though other conclusions might also be reached." (Guidelines §15384) This means that if factual information is presented to the public agency that there is a reasonable possibility the project could have

a significant effect on the environment, an EIR is required even if the public agency has information to the contrary (Guidelines §15064 (f)).

The courts have held that the fair argument standard "establishes a low threshold for initial preparation of an EIR, which reflects a preference for resolving doubts in favor of environmental review." (*Santa Teresa Citizen Action Group v. City of San Jose* [2003] 114 Cal.App.4th 689) Although the determination of whether a fair argument exists is made by the public agency, that determination is subject to judicial scrutiny when challenged in litigation. When the question is whether an EIR should have been prepared, the court will review the administrative record for factual evidence supporting a fair argument.

The fair argument standard essentially empowers project opponents to force preparation of an EIR by introducing factual evidence into the record that asserts that the project may have a significant effect on the environment. This evidence does not need to be conclusive regarding the potential significant effect.

In 1998, the Resources Agency amended the State CEQA Guidelines to encourage the use of thresholds of significance. Guidelines §15064 (h) provided that when a project's impacts did not exceed adopted standards, the impacts were to be considered less than significant. The section went on to describe the types of adopted standards that were to be considered thresholds. Guidelines § 15064.7 provided that agencies may adopt thresholds of significance to guide their determinations of significance. Both of these sections were challenged when environmental groups sued the Resources Agency in 2000 over the amendments. The trial court concluded that §15064.7 was proper, if it was applied in the context of the fair argument standard.



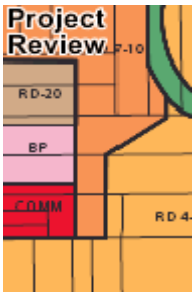
At the appellate court level, §15064(h) was invalidated.[2] Establishing a presumption that meeting an adopted standard would avoid significant impacts was "inconsistent with controlling CEQA law governing the fair argument approach." The Court of Appeal explained that requiring agencies to comply with a regulatory standard "relieves the agency of a duty it would have under the fair argument approach to look at evidence beyond the regulatory standard, or in contravention of the standard, in deciding whether an EIR must be prepared. Under the fair argument approach, any substantial evidence supporting a fair argument that a project may have a significant environmental effect would trigger the preparation of an EIR." (*Communities for a Better Environment v. California Resources Agency* [2002] 103 Cal.App.4th 98)

[2] Prior §15064(h) has been removed from the State CEQA Guidelines. Current §15064(h) discusses cumulative impacts.

In summary, CEQA law does not require a lead agency to establish significance thresholds for GHG. CEQA guidelines encourage the development of thresholds, but the absence of an adopted threshold does not relieve the agency from the obligation to determine significance.

Defensibility of CEQA Analyses

The basic purposes of CEQA, as set out in the State CEQA Guidelines, include: (1) informing decision makers and the public about the significant environmental effects of proposed projects; (2) identifying ways to reduce or avoid those impacts; (3) requiring the implementation of feasible mitigation measures or alternatives that would reduce or avoid those impacts; and (4) requiring public agencies to disclose their reasons for approving any project that would have significant and unavoidable impacts (Guidelines §15002). CEQA is enforced through civil litigation over procedure (i.e., did the public agency follow the correct CEQA procedures?) and adequacy (i.e., has the potential for impacts been disclosed, analyzed, and mitigated to the extent feasible?).



The California Supreme Court has held that CEQA is "to be interpreted in such manner as to afford the fullest possible protection to the environment within the reasonable scope of the statutory language." (*Friends of Mammoth v. Board of Supervisors* [1972] 8 Cal.3d 247, 259) Within that context, the role of the courts is to weigh the facts in each case and apply their judgment. Although the court may rule on the adequacy of the CEQA work, the court is not empowered to act in the place of the public agency to approve or deny the project for which the CEQA document was prepared. Further, the court's review is limited to the evidence contained in the administrative record that was before the public agency when it acted on the project.

Putting aside the issue of CEQA procedure, the defensibility of a CEQA analysis rests on the following concerns:

- whether the public agency has sufficiently analyzed the environmental consequences to enable decision makers to make an intelligent decision;
- whether the conclusions of the public agency are supported by substantial evidence in the administrative record; and
- whether the agency has made a good faith effort at the full disclosure of significant effects.

CEQA analyses need not be perfect or exhaustive -- the depth and breadth of the analysis is limited to what is "reasonably feasible." (Guidelines §15151) At the same time, the analysis "must include detail sufficient to enable those who did not participate in its preparation to understand and to consider meaningfully the issues raised by the proposed

project." (Laurel Heights Improvement Assn. v. Regents of University of California (1988) 47 Cal.3d 376)

By itself, establishment of a GHG threshold will not insulate individual CEQA analyses from challenge. Defensibility depends upon the adequacy of the analysis prepared by the lead agency and the process followed. However, the threshold can help to define the boundaries of what is a reasonable analysis by establishing when an analysis will be required and the basic scope of that analysis. The threshold would attempt to define the point at which an analysis will be required and when a level of impact becomes significant, requiring preparation of an EIR. If the threshold includes recommendations for the method or methods of analysis, it can establish the minimum level of analysis to address this issue.

Considerations in Setting Thresholds for Stationary Source Projects

In many respects, the analysis of GHG emissions from stationary sources is much more straightforward than the analysis of land use patterns, forecasted energy consumption, and emissions from mobile sources. The reason is that, for the most part, the latter analyses depend largely on predictive models with myriad inputs and have a wider range of error. Emissions from stationary sources involve a greater reliance on mass and energy balance calculations and direct measurements of emissions from the same or similar sources. Energy demand is more directly tied to production, and even associated mobile source emissions will likely fall within narrower predictive windows.

<u>Implementing CEQA Without a Threshold</u>

A lead agency is not required to establish significance thresholds for GHG emissions from stationary sources. The lead agency may find that it needs more information or experience evaluating GHG from these types of projects to determine an appropriate significance threshold. As with other project types, the lead agency could conduct a project specific analysis to determine whether an environmental impact report is needed and to determine the level of mitigation that is appropriate. The agency might also rely on thresholds established for criteria pollutants as a screening method, and analyze GHG emissions (and require mitigation) from projects with emissions above the criteria pollutant thresholds. Over time, the agency could amass information and experience with specific project categories that would support establishing explicit thresholds. The lead agency may also choose to base local CEQA thresholds on state guidelines or on the category-specific reduction targets established by ARB in its scoping plan for implementing AB32. Resource constraints and other considerations associated with implementing CEQA without GHG thresholds for stationary sources would be similar to those outlined for other types of projects (see Chapter 5 – No Threshold Option).

Implementing CEQA with Threshold of Zero

A lead agency may find that any increase in GHG emissions is potentially significant under CEQA. The resources and other considerations for implementing a threshold of zero for stationary sources are the same as those outlined for other types of projects (see Chapter 6 – Zero Threshold Option).

Implementing CEQA with a Non-Zero Threshold

A lead agency may identify one or more non-zero thresholds for significance of emissions of GHG from stationary sources. The agency could elect to rely on existing thresholds for reviewing new or modified stationary sources of GHG, if the state or local air district has established any. The agency could also apply the threshold(s) established for non-stationary sources to GHG emissions from stationary sources. Significance thresholds could also be established by ordinance, rule, or policy for a given category of stationary sources; this approach is especially conducive to a tiered threshold approach. For example, the agency could establish significance and mitigation tiers for stationary compression-ignition diesel-fueled generators. Under such an approach, the project proponent could be first required to use a lower GHG-emitting power source if feasible, and if not, to apply mitigation based on the size of the generator and other defined considerations, such as hours of operation. Certain classes of generators could be found to be insignificant under CEQA (e.g., those used for emergency stand-by power only, with a limit on the annual hours of use). As with non-stationary projects, the goal of establishing non-zero thresholds is to maximize environmental protection, while minimizing resources used. Resource and other considerations outlined for non-stationary projects are applicable here (see Chapter 7 – Non-Zero Threshold Options).

Implementing CEQA with Different Thresholds for Stationary and Non-stationary Projects

Although a lead agency may apply the same thresholds to stationary and non-stationary projects, it is not required to do so. There are, in fact, some important distinctions between the two types of projects that could support applying different thresholds. The lead agency should consider the methods used to estimate emissions. Are the estimates a "best/worst reasonable scenario" or are they based on theoretical maximum operation? How accurate are the estimates (are they based on models, simulations, emission factors, source test data, manufacturer specifications, etc.)? To what extent could emissions be reduced through regulations after the project is constructed if they were found to be greater than originally expected (i.e., is it possible to retrofit emissions control technology onto the source(s) of GHG at a later date, how long is the expected project life, etc.)? Are there emission limits or emissions control regulations (such as New Source Review) that provide certainty that emissions will be mitigated? Generally, stationary source emissions are based on maximum emissions (theoretical or allowed under law or regulation), are more accurate, and are more amenable to retrofit at a later time than non-stationary source emissions. It is also more likely that category specific

rules or some form of NSR will apply to stationary sources than non-stationary projects. Notwithstanding, it is almost always more effective and cost-efficient to apply emission reduction technology at the design phase of a project. There are, therefore, a number of considerations that need to be evaluated and weighed before establishing thresholds – and which may support different thresholds for stationary and non-stationary projects. Furthermore, the considerations may change over time as new regulations are established and as emissions estimation techniques and control technology evolves.

Direct GHG Emissions from Stationary Sources

The main focus of this paper has been the consideration of projects that do not, in the main, involve stationary sources of air pollution, because stationary source projects are generally a smaller percentage of the projects seen by most local land use agencies. That said, some discussion of stationary sources is warranted. As the broader program for regulating GHG from these sources is developed, the strategies for addressing them under CEQA will likely become more refined.

The primary focus of analysis of stationary source emissions has traditionally been those pollutants that are directly emitted by the source, whether through a stack or as fugitive releases (such as leaks). CAPCOA conducted a simplified analysis of permitting activity to estimate the number of stationary source projects with potentially significant emissions of greenhouse gases that might be seen over the course of a year. This analysis looked only at stationary combustion sources (such as boilers and generators), and only considered direct emissions. A lead agency under CEQA may see a different profile of projects than the data provided here suggest, depending on what other resources are affected by projects. In addition, air districts review like-kind replacements of equipment to ensure the new equipment meets current standards, but such actions might not constitute a project for many land use agencies or other media regulators. The data does provide a useful benchmark, however, for lead agencies to assess the order of magnitude of potential stationary source projects. A similar analysis is included for non-stationary projects in Chapter 7.

Table 1: Analysis of GHG Emissions from Stationary Combustion Equipment Permits[3]

	BAAQMD	SMAQMD	SJVUAPCD	SCAQMD
Total Applications for Year	1499	778	1535	1179
Affected at threshold of:				
900 metric tons/year	26	43	63	108
10,000 metric tons/year	7	5	26	8
25,000 metric tons/year	3	1	11	4

[3] District data varies based on specific local regulations and methodologies.

Emissions from Energy Use

In addition to the direct emissions of GHG from stationary projects, CEQA will likely need to consider the project's projected energy use. This could include an analysis of opportunities for energy efficiency, onsite clean power generation (e.g., heat/energy recovery, co-generation, geothermal, solar, or wind), and the use of dedicated power contracts as compared to the portfolio of generally available power. In some industries, water use and conservation may provide substantial GHG emissions reductions, so the CEQA analysis should consider alternatives that reduce water consumption and wastewater discharge. The stationary project may also have the opportunity to use raw or feedstock materials that have a smaller GHG footprint; material substitution should be evaluated where information is available to do so.

Emissions from Associated Mobile Sources

The stationary project will also include emissions from associated mobile sources. These will include three basic components: emissions from employee trips, emissions from delivery of raw or feedstock materials, and emissions from product transport. Employee trips can be evaluated using trip estimation as is done for non-stationary projects, and mitigations would include such measures as providing access to and incentives for use of public transportation, accessibility for bicycle and pedestrian modes of transport, employer supported car or vanpools (including policies such as guaranteed rides home, etc). Upstream and downstream emissions related to goods movement can also be estimated with available models. The evaluation will need to determine the extent of the transport chain that should be included (to ensure that all emissions in the chain have been evaluated and mitigated, but to avoid double counting). Mitigations could include direct actions by operators who own their own fleet, or could be implemented through contractual arrangements with independent carriers; again, the evaluation will need to consider how far up and down the chain mitigation is feasible and can be reasonably required.

Comparing Emissions Changes Across Pollutant Categories

The potential exists for certain GHG reduction measures to increase emissions of criteria and toxic pollutants known to cause or aggravate respiratory, cardiovascular, and other health problems. For instance, GHG reduction efforts such as alternative fuels and methane digesters may create significant levels of increased pollutants that are detrimental to the health of the nearby population (e.g.; particulate matter, ozone precursors, toxic air contaminants). Such considerations should be included in any CEQA analysis of a project's environmental impacts. While there are many win-win

strategies that can reduce both GHG and criteria/toxic pollutant emissions, when faced with situations that involve tradeoffs between the two, the more immediate public health concerns that may arise from an increase in criteria or toxic pollutant emissions should take precedence. GHG emission reductions could be achieved offsite through other mitigation programs.

Introduction

Under state law, it is the purview of each lead agency to determine what, if any, significance thresholds will be established to guide its review of projects under CEQA. While the state does provide guidelines for implementing CEQA, the guidelines have left the decision of whether to establish thresholds (and if so, at what level) to individual lead agencies. Frequently, lead agencies consult with resource-specific agencies (such as air districts) for assistance in determining what constitutes a significant impact on that specific resource.

With the passage of AB 32, the ARB has broad authority to regulate GHG emissions as necessary to meet the emission reduction goals of the statute. This may include authority to establish emission reduction requirements for new land use projects, and may also enable them to recommend statewide thresholds for GHG under CEQA.

In developing this white paper, CAPCOA recognizes that, as the GHG reduction program evolves over time, GHG thresholds and other policies and procedures for CEQA may undergo significant revision, and that uniform statewide thresholds and procedures may be established. This paper is intended to serve as a resource for public agencies until such time that statewide guidance is established, recognizing that decisions will need to be made about GHG emissions from projects before such guidance is available. This paper is not, however, uniform statewide guidance. As stated before, it outlines several possible approaches without endorsing any one over the others.

Some air districts may choose to use this paper to support their establishment of guidance for GHG under CEQA, including thresholds. This paper does not, nor should it be construed to require a district to implement any of the approaches evaluated here. Decisions about whether to provide formal local guidance on CEQA for projects with GHG emissions, including the question of thresholds, will be made by individual district boards.

Each of the 35 air districts operates independently and has its own set of regulations and programs to address the emissions from stationary, area and mobile sources, consistent with state and federal laws, regulations, and guidelines. The independence of the districts allows specific air quality problems to be addressed on a local level. In addition, districts have also established local CEQA thresholds of significance for criteria pollutants – also to address the specific air quality problems relative to that particular district.

The overall goal of air district thresholds is to achieve and maintain health based air quality standards within their respective air basins and to reduce transport of emissions to other air basins. In establishing recommended thresholds, air districts consider the existing emission inventory of criteria pollutants and the amount of emission reductions needed to attain and maintain ambient air quality standards.

However, unlike criteria pollutants where individual districts are characterized by varying levels of pollutant concentrations and source types, greenhouse gases (GHG) and their attendant climate change ramifications are a global problem and, therefore, may suggest a uniform approach to solutions that ensure both progress and equity.

Under SB97, the Office of Planning and Research is directed to prepare, develop, and transmit to the Resources Agency guidelines for the feasible mitigation of GHG emissions or the effects of GHG emissions through CEQA by July 1, 2009. Those guidelines may recommend thresholds. As stated, this paper is intended to provide a common platform of information and tools to support local decision makers until such time that statewide guidance or requirements are promulgated.

Local Ability to Promulgate District-Specific GHG Thresholds

One of the primary reasons behind the creation of air districts in California is the recognition that some regions within the state face more critical air pollution problems than others and, as has often been pointed out – one size does not fit all. For example, a "Serious" federal nonattainment district would need greater emission reductions than a district already in attainment – and, therefore, the more "serious" district would set its criteria pollutant CEQA thresholds of significance much lower than the air district already in attainment.

The action of GHGs is global in nature, rather than local or regional (or even statewide or national). Ultimately there may be a program that is global, or at least national in scope. That said, actions taken by a state, region, or local government can contribute to the solution of the global problem. Local governments are not barred from developing and implementing programs to address GHGs. In the context of California and CEQA, lead agencies have the primary responsibility and authority to determine the significance of a project's impacts.

Further, air districts have primary authority under state law for "control of air pollution from all sources, other than emissions from motor vehicles." (H&SC §40000) The term air contaminant or "air pollutant" is defined extremely broadly, to mean "any discharge, release, or other propagation into the atmosphere" and includes, but is not limited to, soot, carbon, fumes, gases, particulate matter, etc. Greenhouse gases and other global warming pollutants such as black carbon would certainly be included in this definition, just as the U.S. Supreme Court held in Massachusetts v. EPA that greenhouse gases were air pollutants under the federal Clean Air Act. Therefore, air districts have the primary authority to regulate global warming pollutants from nonvehicular sources. AB 32 does not change this result. Although it gives wide responsibility to CARB to regulate greenhouse gases from all sources, including nonvehicular sources, it does not preempt the districts. AB 32 specifically states That "nothing in this division shall limit or expand the existing authority of any district..."(H&SC § 38594). Thus, districts and CARB retain concurrent authority over nonvehicular source greenhouse gas emissions.

Introduction

The CEQA statutes do not require an air district or any lead agency to establish significance thresholds under CEQA for any pollutant. While there are considerations that support the establishment of thresholds (which are discussed in other sections of this document), there is no obligation to do so.

An air district or other lead agency may elect not to establish significance thresholds for a number of reasons. The agency may believe that the global nature of the climate change problem necessitates a statewide or national framework for consideration of environmental impacts. SB 97 directs OPR to develop "guidelines for the mitigation of greenhouse gas emissions or the effects of greenhouse gas emissions by July 1, 2009," and directs the California Resources Agency to certify and adopt the guidelines by June 30, 2010.

An agency may also believe there is insufficient information to support selecting one specific threshold over another. As described earlier, air districts have historically set CEQA thresholds for air pollutants in the context of the local clean air plan, or (in the case of toxic air pollutants) within the framework of a rule or policy that manages risks and exposures due to toxic pollutants. There is no current framework that would similarly manage impacts of greenhouse gas pollutants, although the CARB is directed to establish one by June 30, 2009, pursuant to AB 32. A local agency may decide to defer any consideration of thresholds until this framework is in place.

Finally, an agency may believe that the significance of a given project should be assessed on a case-by-case basis in the context of the project at the time it comes forward.

Implementing CEQA Without Significance Thresholds for GHG

The absence of a threshold does not in any way relieve agencies of their obligations to address GHG emissions from projects under CEQA. The implications of not having a threshold are different depending on the role the agency has under CEQA – whether it is acting in an advisory capacity, as a responsible agency, or as a lead agency.

<u>Implications of No Thresholds for an Agency Acting in an Advisory Capacity</u>

Air districts typically act in an advisory capacity to local governments in establishing the framework for environmental review of air pollution impacts under CEQA. This may include recommendations regarding significance thresholds, analytical tools to assess emissions and impacts, and mitigations for potentially significant impacts. Although districts will also address some of these issues on a project-specific basis as responsible agencies, they may provide general guidance to local governments on these issues that

are program wide, and these are advisory (unless they have been established by regulation).

An air district that has not established significance thresholds for GHG will not provide guidance to local governments on this issue. This does not prevent the local government from establishing thresholds under its own authority. One possible result of this would be the establishment of different thresholds by cities and counties within the air district. Alternatively, the air district could advise local governments not to set thresholds and those jurisdictions may follow the air district's guidance.

It is important to note here (as has been clearly stated by the Attorney General in comments and filings) that lack of a threshold does *not* mean lack of significance. An agency may argue lack of significance for any project, but that argument would have to be carried forth on a case-by-case, project specific basis. By extension then, a decision not to establish thresholds for GHG is likely to result in a greater workload for responsible and lead agencies as they consider individual projects under CEQA.

Implications of No Thresholds for a Responsible Agency

If there are no established thresholds of significance, the significance of each project will have to be determined during the course of review. The responsible agency (e.g., the air district) will review each project referred by the lead agency. The review may be qualitative or quantitative in nature. A qualitative review would discuss the nature of GHG emissions expected and their potential effect on climate change as the district understands it. It could also include a discussion of the relative merits of alternative scenarios. A quantitative analysis would evaluate, to the extent possible, the expected GHG emissions; it would also need to evaluate their potential effect on climate change and might include corresponding analysis of alternatives. The air district, as a responsible agency, may also identify mitigation measures for the project.

The lack of established thresholds will make the determination of significance more resource intensive for each project. The district may defer to the lead agency to make this determination, however the district may be obligated, as a responsible agency, to evaluate the analysis and determination.

Implications of No Thresholds for a Lead Agency

The main impact of not having significance thresholds will be on the primary evaluation of projects by the lead agency. Without significance thresholds, the agency will have to conduct some level of analysis of every project to determine whether an environmental impact report is needed. There are three fundamental approaches to the case-by-case analysis of significance, including presumptions of significance or insignificance, or no presumption:

1. The agency can begin with a presumption of significance and the analysis would be used to support a case-specific finding of no significance. This is similar to establishing a threshold of zero, except that here, the "threshold" is rebuttable. This approach may result in a large number of projects proceeding to preparation of an environmental impact report. Because of the attendant costs, project proponents may challenge the determination of significance, although formal challenge is less likely than attempts to influence the determination.

2. The agency can begin with a presumption of insignificance, and the analysis would be used to support a case-specific finding of significance. A presumption of insignificance could be based on the perspective that it would be speculative to attempt to identify the significance of GHG emissions from a project relative to climate change on a global scale. This approach might reduce the number of projects proceeding to preparation of environmental impact reports. It is likely to have greater success with smaller projects than larger ones, and a presumption of *insignificance* may be more likely to be challenged by project opponents.

3. It is not necessary for the lead agency to have any presumption either way. The agency could approach each project from a *tabula rasa* perspective, and have the determination of significance more broadly tied to the specific context of the project; this approach is likely to be resource intensive, and creates the greatest uncertainty for project proponents. To the extent that it results in a lead agency approving similar projects based on different determinations of significance for GHG emissions, it may be more vulnerable to challenge from either proponents or opponents of the project. Alternatively, in the absence of either thresholds or presumptions, the lead agency could use each determination of significance to build its approach in the same way that subsequent judgments define the law.

Relevant Citations

The full text of relevant citations is in Appendix A.

Public Resources Code – §21082.2, Significant Effect on Environment; Determination; Environmental Impact Report Preparation.

State CEQA Guidelines – §15064, Determining the Significance of the Environmental Effects Caused by a Project.

Introduction

If an air district or lead agency determines that any degree of project-related increase in GHG emissions would contribute considerably to climate change and therefore would be a significant impact, it could adopt a zero-emission threshold to identify projects that would need to reduce their emissions. A lead agency may determine that a zero-emission threshold is justified even if other experts may disagree. A lead agency is not prevented from adopting any significance threshold it sees as appropriate, as long as it is based on substantial evidence.

If the zero threshold option is chosen, all projects subject to CEQA would be required to quantify and mitigate their GHG emissions, regardless of the size of the project or the availability of GHG reduction measures available to reduce the project's emissions. Projects that could not meet the zero-emission threshold would be required to prepare environmental impact reports to disclose the unmitigable significant impact, and develop the justification for a statement of overriding consideration to be adopted by the lead agency.

Implementing CEQA With a Zero Threshold for GHG

The scientific community overwhelmingly agrees that the earth's climate is becoming warmer, and that human activity is playing a role in climate change. Unlike other environmental impacts, climate change is a global phenomenon in that all GHG emissions generated throughout the earth contribute to it. Consequently, both large and small GHG generators cause the impact. While it may be true that many GHG sources are individually too small to make any noticeable difference to climate change, it is also true that the countless small sources around the globe combine to produce a very substantial portion of total GHG emissions.

A zero threshold approach is based on a belief that, 1) all GHG emissions contribute to global climate change and could be considered significant, and 2) not controlling emissions from smaller sources would be neglecting a major portion of the GHG inventory.

CEQA explicitly gives lead agencies the authority to choose thresholds of significance. CEQA defers to lead agency discretion when choosing thresholds. Consequently, a zero-emission threshold has merits.

The CEQA review process for evaluating a project's impact on global climate change under the zero threshold option would involve several components. Air quality sections would be written by lead agencies to include discussions on climate change in CEQA documents, GHG emissions would be calculated, and a determination of significance would be made. The local air districts would review and comment on the climate change discussions in environmental documents. Lead agencies may then revise final EIRs to accommodate air district comments. More than likely, mitigation measures will be specified for the project, and a mitigation monitoring program will need to be put in place to ensure that these measures are being implemented.

Since CEQA requires mitigation to a less than significant level, it is conceivable that many projects subjected to a zero threshold could only be deemed less than significant with offsite reductions or the opportunity to purchase greenhouse gas emission reduction credits. GHG emission reduction credits are becoming more readily available however the quality of the credits varies considerably. High quality credits are generated by actions or projects that have clearly demonstrated emission reductions that are real, permanent, verifiable, enforceable, and not otherwise required by law or regulation. When the pre- or post-project emissions are not well quantified or cannot be independently confirmed, they are considered to be of lesser quality. Similarly, if the reductions are temporary in nature, they are also considered to be poor quality. Adoption of a zero threshold should consider the near-term availability and the quality of potential offsets.

There are also environmental justice concerns about the effects of using offsite mitigations or emission reduction credits to offset, or mitigate, the impacts of a new project. Although GHGs are global pollutants, some of them are emitted with co-pollutants that have significant near-source or regional impacts. Any time that increases in emissions at a specific site will be mitigated at a remote location or using emission reduction credits, the agency evaluating the project should ensure that it does not create disproportionate impacts.

Administrative Considerations

If electing to pursue a zero threshold, an air district or lead agency should consider the administrative costs and the environmental review system capacity. Some projects that previously would have qualified for an exemption could require further substantial analysis, including preparation of a Negative Declaration (ND), a Mitigated Negative Declaration (MND) or an EIR. Moreover, the trade-offs between the volume of projects requiring review and the quality of consideration given to reviews should be considered. It may also be useful to consider whether meaningful mitigation can be achieved from smaller projects.

Consideration of Exemptions from CEQA

A practical concern about identifying GHG emissions as a broad cumulative impact is whether the zero threshold option will preclude a lead agency from approving a large set of otherwise qualified projects utilizing a Categorical Exemption, ND, or MND. The results could be a substantial increase in the number of EIR's. This is a valid and challenging concern, particularly for any threshold approach that is based on a zero threshold for net GHG emission increases.

CEQA has specified exceptions to the use of a categorical exception. Specifically, CEQA Guidelines §15300.2 includes the following exceptions:

"(b) Cumulative Impact. All exemptions for these classes are inapplicable when the cumulative impact of successive projects of the same type in the same place, over time is significant."

(c) Significant Effect. A categorical exemption shall not be used for an activity where there is a reasonable possibility that the activity will have a significant effect on the environment due to unusual circumstances."

These CEQA Guidelines sections could be argued to mean that any net increase in GHG emissions would preclude the use of a categorical exemption. However, as described below, if the following can be shown, then the exceptions above could be argued not to apply:

(1) Cumulative local, regional and/or state GHG emissions are being reduced or will be reduced by adopted, funded, and feasible measures in order to meet broader state targets.

(2) Mandatory state or local GHG reduction measures would apply to the project's emissions such that broader GHG reduction goals would still be met and the project contributions would not be cumulatively considerable.

(3) Project GHG emissions are below an adopted significance threshold designed to take into account the cumulative nature of GHG emissions.

A similar argument could be made relative to the use of a ND (provided no additional mitigation (beyond existing mandates) is required to control GHG emissions) and to the use of a MND instead of an EIR. However, due to the "fair argument" standard, which is discussed in Chapter 3, caution is recommended in use of a ND or MND unless all three elements above can be fully supported through substantial evidence and there is no substantial evidence to the contrary. Establishing a significance threshold of zero is likely to preclude the use of a categorical exemption.

Relevant Citations

The full text of relevant citations is in Appendix A.

Public Resources Code – §21004, Mitigating or Avoiding a Significant Effect; Powers of Public Agency.

State CEQA Guidelines – §15064, Determining the Significance of the Environmental Effects Caused by a Project.

State CEQA Guidelines – §15130, Discussion of Cumulative Impacts.

State CEQA Guidelines – §15064.7, Thresholds of Significance.

Introduction

A non-zero threshold could minimize the resources spent reviewing environmental analyses that do not result in real GHG reductions or to prevent the environmental review system from being overwhelmed. The practical advantages of considering non-zero thresholds for GHG significance determinations can fit into the concept regarding whether the project's GHG emissions represent a "considerable contribution to the cumulative impact" and therefore warrant analysis.

Specifying a non-zero threshold could be construed as setting a *de minimis* value for a cumulative impact. In effect, this would be indicating that there are certain GHG emission sources that are so small that they would not contribute substantially to the global GHG budget. This could be interpreted as allowing public agencies to approve certain projects without requiring any mitigation of their GHG. Any threshold framework should include a proper context to address the *de minimis* issue. However, the CEQA Guidelines recognize that there may be a point where a project's contribution, although above zero, would not be a *considerable contribution* to the cumulative impact and, therefore, not trigger the need for a significance determination.

GHG emissions from all sources are under the purview of CARB and as such may eventually be "regulated" no matter how small. Virtually all projects will result in some direct or indirect release of GHG. However, a decision by CARB to regulate a class of sources does not necessarily mean that an individual source in that class would constitute a project with significant GHG impacts under CEQA. For example, CARB has established criteria pollutant emission standards for automobiles, but the purchase and use of a single new car is not considered a project with significant impacts under CEQA. At the same time, it is important to note that it is likely that all meaningful sources of emissions, no matter how small are likely to be considered for regulation under AB 32. It is expected that projects will have to achieve some level of GHG reduction to comply with CARB's regulations meant to implement AB 32. As such all projects will have to play a part in reducing our GHG emissions budget and no project, however small, is truly being considered *de minimis* under CARB's regulations.

This chapter evaluates a range of conceptual approaches toward developing GHG significance criteria. The air districts retained the services of J&S an environmental consulting, firm to assist with the development of a Statute and Executive Order-based threshold (Approach 1) and a tiered threshold (Approach 2) based on a prescribed list of tasks and deliverables. Time and financial constraints limited the scope and depth of this analysis, however, the work presented here may be useful in developing interim guidance while AB 32 is being implemented. J&S recognized that approaches other than those described here could be used.

As directed, J&S explored some overarching issues, such as:

- what constitutes "new" emissions?

- how should "baseline emissions" be established?
- what is cumulatively "considerable" under CEQA?
- what is "business as usual" ? and
- should an analysis include "life-cycle" emissions?

The answers to these issues were key to evaluating each of the threshold concepts.

Approach 1 – Statute and Executive Order Approach

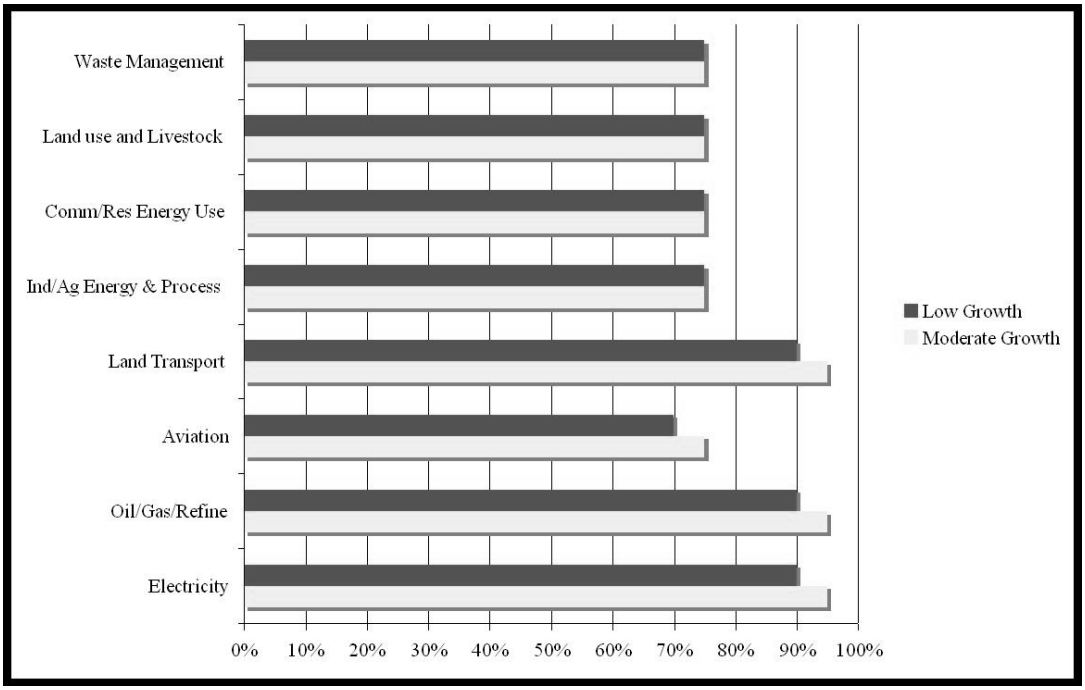
Thresholds could be grounded in existing mandates and their associated GHG emission reduction targets. A project would be required to meet the targets, or reduce GHG emissions to the targets, to be considered less than significant.

AB 32 and S-3-05 target the reduction of statewide emissions. It should be made clear that AB 32 and S-3-05 do not specify that the emissions reductions should be achieved through uniform reduction by geographic location or by emission source characteristics. For example, it is conceivable, although unlikely, that AB 32 goals could be achieved by new regulations that only apply to urban areas or that only apply to the transportation and/or energy sector. However, this approach to evaluating GHG under CEQA is based on the presumption that a new project must at least be consistent with AB 32 GHG emission reduction mandates.

The goal of AB 32 and S-3-05 is the significant reduction of future GHG emissions in a state that is expected to rapidly grow in both population and economic output. As such, there will have to be a significant reduction in the per capita GHG output for these goals to be met. CEQA is generally used to slow or zero the impact of new emissions, leaving the reduction of existing emission sources to be addressed by other regulatory means. With these concepts in mind, four options were identified for statute/executive order-based GHG significance thresholds and are described below.

<u>Threshold 1.1: AB 32/S-3-05 Derived Uniform Percentage-Based Reduction.</u> AB 32 requires the state to reduce California-wide GHG emissions to 1990 levels by 2020. Reducing greenhouse gas emission levels from 2020 to 1990 levels could require a 28 to 33 percent reduction of business-as-usual GHG emissions depending on the methodology used to determine the future emission inventories. The exact percent reduction may change slightly once CARB finalizes its 1990 and 2020 inventory estimates. In this context, business-as-usual means the emissions that would have occurred in the absence of the mandated reductions. The details of the business-as-usual scenario are established by CARB in the assumptions it uses to project what the state's GHG emissions would have been in 2020, and the difference between that level and the level that existed in 1990 constitutes the reductions that must be achieved if the mandated goals are to be met.

This threshold approach would require a project to meet a percent reduction target based on the average reductions needed from the business-as-usual emission from all GHG sources. Using the 2020 target, this approach would require all discretionary projects to achieve a 33 percent reduction from projected business-as-usual emissions in order to be considered less than significant. A more restrictive approach would use the 2050 targets. S-3-05 seeks to reduce GHG emissions to 80 percent below 1990 levels by 2050. To reach the 2050 milestone would require an estimated 90 percent reduction (effective immediately) of business-as-usual emissions. Using this goal as the basis for a significance threshold may be more appropriate to address the long-term adverse impacts associated with global climate change. Note that AB 32 and S-3-05 set emission inventory goals at milestone years; it is unclear how California will progress to these goals in non-milestone years.



SOURCE: ARB 2007

<u>Threshold 1.2: Uniform Percentage-Based (e.g.50%) Reduction for New Development</u>. This threshold is based on a presumption that new development should contribute a greater percent reduction from business-as-usual because greater reductions can be achieved at lower cost from new projects than can be achieved from existing sources. This approach would establish that new development emit 50 percent less GHG emissions than business-as-usual development. This reduction rate is greater than the recommended reduction rate for meeting the Threshold 1.1 2020 target (33 percent) but is significantly less restrictive than the Threshold 1.1 2050 target reduction rate (90 percent). If a 50 percent GHG reduction were achieved from new development, existing emissions would have to be reduced by 25 to 30 percent in order to meet the 2020 emissions goal depending on the year used to determine the baseline inventory. Although this reduction goal is reasonable for achieving the 2020 goal, it would not be possible to

reach the 2050 emissions target with this approach even if existing emissions were 100 percent controlled.

Threshold 1.3: Uniform Percentage-Based Reduction by Economic Sector. This threshold would use a discrete GHG reduction goal specific to the economic sector associated with the project. There would be specific reduction goals for each economic sector, such as residential, commercial, and industrial development. Specifying different reduction thresholds for each market sector allows selection of the best regulatory goal for each sector taking into account available control technology and costs. This approach would avoid over-regulating projects (i.e. requiring emissions to be controlled in excess of existing technology) or under-regulating projects (i.e. discouraging the use of available technology to control emissions in excess of regulations). This approach requires extensive information on the emission inventories and best available control technology for each economic sector. This data will be compiled as CARB develops its scoping plan under AB 32 and its implementing regulations; as a result, this approach will be more viable in the long term.

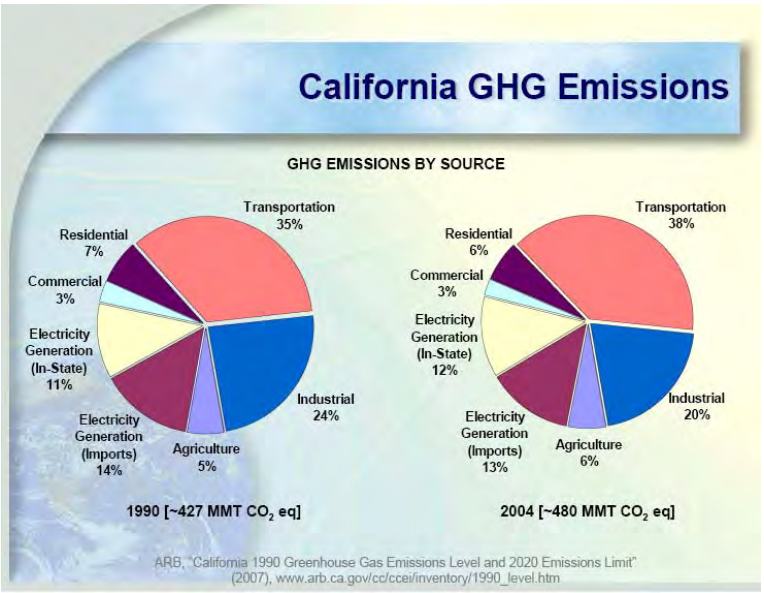
Threshold 1.4: Uniform Percentage-Based Reduction by Region. AB 32 and S-3-05 are written such that they apply to a geographic region (i.e. the entire state of California) rather than on a project or sector level. One could specify regions of the state such as the South Coast Air Basin, Sacramento Valley, or Bay Area which are required to plan (plans could be developed by regional governments, such as councils of governments) and demonstrate compliance with AB 32 and S-3-05 reduction goals at a regional level. To demonstrate that a project has less than significant emissions, one would have to show compliance with the appropriate regional GHG plan. Effectively this approach allows for analysis of GHG emissions at a landscape scale smaller than the state as a whole. Specifying regions in rough correlation to existing air basins or jurisdictional control allows for regional control of emissions and integration with regional emission reduction strategies for criteria and toxic air pollutants. Although differing GHG reduction controls for each region are possible, it is likely that all regions would be

required to achieve 1990 emission inventories by the year 2020 and 80 percent less emissions by 2050. Threshold 1.4 is considered viable long-term significance criteria that is unlikely to be used in the short term.

Implementing CEQA Thresholds Based on Emission Reduction Targets

Characterizing Baseline and Project Emissions

While the population and economy of California is expanding, all new projects can be considered to contribute new emissions. Furthermore, GHG impacts are exclusively cumulative impacts; there are no non-cumulative GHG emission impacts from a climate change perspective. "Business-as-usual" is the projection of GHG emissions at a future date based on current technologies and regulatory requirements in absence of other reductions. For example to determine the future emissions from a power plant for "business-as-usual" one would multiply the projected energy throughput by the current emission factor for that throughput. If adopted regulations (such as those that may be promulgated by CARB for AB 32) dictate that power plant emissions must be reduced at some time in the future, it is appropriate to consider these regulation standards as the new business-as-usual for a future date. In effect, business-as-usual will continue to evolve as regulations manifest. Note that "business-as-usual" defines the CEQA No Project conditions, but does not necessarily form the baseline under CEQA. For instance, it is common to subtract the future traffic with and without a project to determine the future cumulative contribution of a project on traffic conditions. However, existing conditions at the time of issuance of the notice of preparation is normally the baseline.



SOURCE: ARB 2007

Establishing Emission Reduction Targets

One of the obvious drawbacks to using a uniform percent reduction approach to GHG control is that it is difficult to allow for changes in the 1990 and future emission inventories estimates. To determine what emission reductions are required for new projects one would have to know accurately the 1990 budget and efficacy of other GHG promulgated regulations as a function of time. Since CARB will not outline its

regulation strategy for several more years, it is difficult to determine accurately what the new project reductions should be in the short term. Future updates to the 1990 inventory could necessitate changes in thresholds that are based on that inventory. It is important to note that it is difficult to create near term guidance for a uniform reduction threshold strategy since it would require considerable speculation regarding the implementation and effectiveness of forthcoming CARB regulations.

Of greater importance are the assumptions used to make the projected 2020 emission inventories. Projecting future inventories over the next 15-50 years involves substantial uncertainty. Furthermore, there are likely to be federal climate change regulations and possibly additional international GHG emission treaties in the near future. To avoid such speculation, this paper defines all future emission inventories as hypothetical business-as-usual projections.

This white paper is intended to support local decisions about CEQA and GHG in the near term. During this period, it is unlikely that a threshold based on emission reduction targets would need to be changed. However, it is possible that future inventory updates will show that targets developed on the current inventory were not stringent enough, or were more stringent than was actually needed.

Approach 2 – Tiered Approach

The goal of a tiered threshold is to maximize reduction predictability while minimizing administrative burden and costs. This would be accomplished by prescribing feasible mitigation measures based on project size and type, and reserving the detailed review of an EIR for those projects of greater size and complexity. This approach may require inclusion in a General Plan, or adoption of specific rules or ordinances in order to fully and effectively implement it.

A tiered CEQA significance threshold could establish different levels at which to determine if a project would have a significant impact. The tiers could be established based on the gross GHG emission estimates for a project or could be based on the physical size and characteristics of the project. This approach would then prescribe a set of GHG mitigation strategies that would have to be incorporated into the project in order for the project to be considered less than significant.

The framework for a tiered threshold would include the following:

- disclosure of GHG emissions for all projects;
- support for city/county/regional GHG emissions reduction planning;
- creation and use of a “green list” to promote the construction of projects that have desirable GHG emission characteristics;
- a list of mitigation measures;

- a decision tree approach to tiering; and
- quantitative or qualitative thresholds.

Decision-Tree Approach to Tiering

CEQA guidance that allows multiple methodologies to demonstrate GHG significance will facilitate the determination of significance for a broad range of projects/plans that would otherwise be difficult to address with a single non-compound methodology. Even though there could be multiple ways that a project can determine GHG significance using a decision-tree approach, only one methodology need be included in any single CEQA document prepared by the applicant. The presence of multiple methodologies to determine significance is designed to promote flexibility rather than create additional analysis overhead. Figure 1 shows a conceptual approach to significance determination using a tiered approach that shows the multiple routes to significance determination.

Figure 1 Detail Description

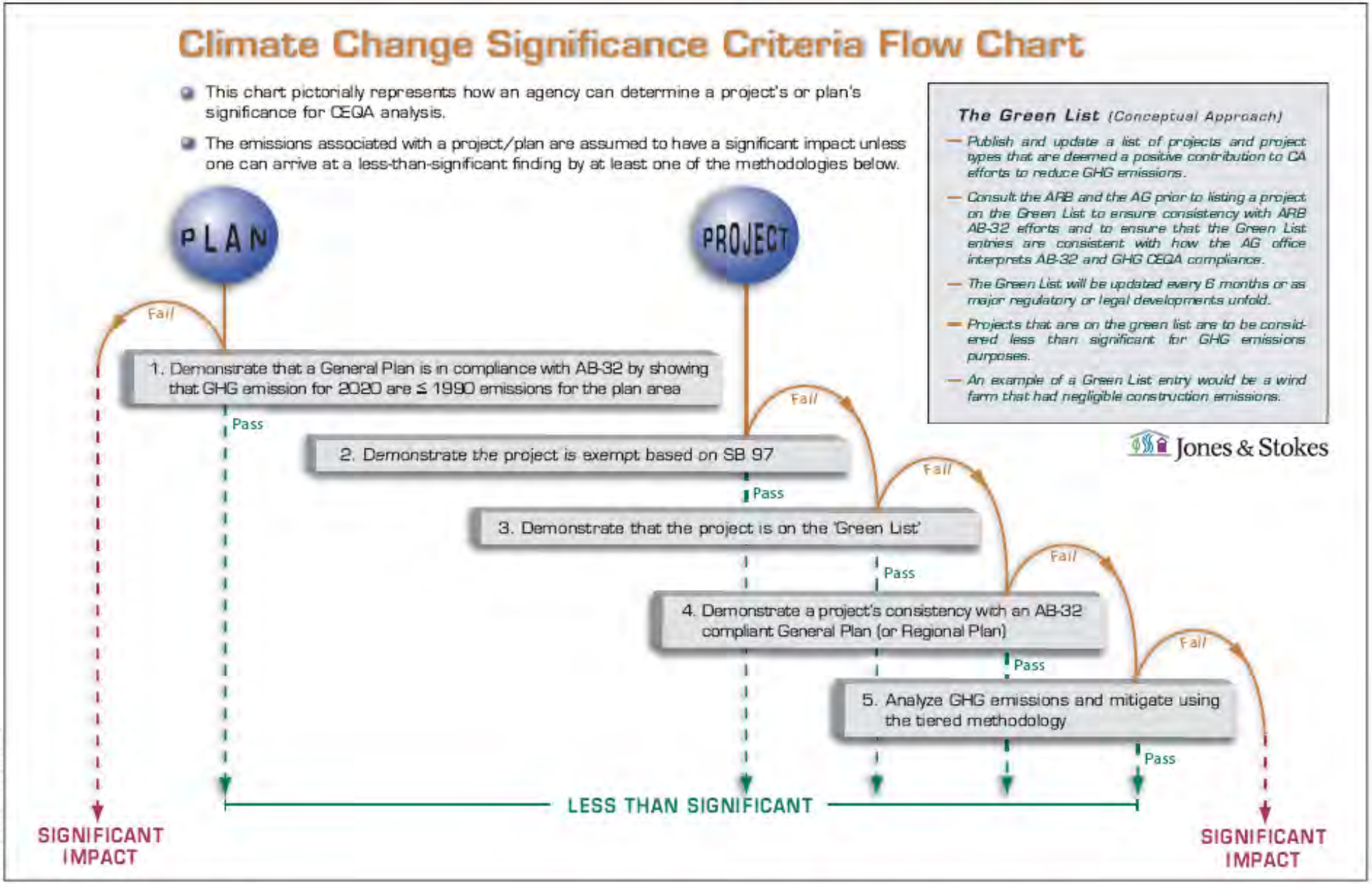
Figure 1 pictorially represents how an agency can determine a project's or plan's significance for CEQA analysis using the non-zero threshold methodology. The emissions associated with a project/plan are assumed to have a significant impact unless one can arrive at a less-than-significant finding by at least one of the methodologies below.

1. Demonstrate that a General Plan (GP) or Regional Plan is in Compliance with AB32

   - For most GPs or RPs this will require demonstration that projected 2020 emissions will be equal to or less than 1990 emissions.
   - GPs or RPs are expected to fully document 1990 and 2020 GHG emission inventories.
   - Projection of 2020 emissions is complicated by the fact that CARB is expected to promulgate emission reductions in the short term. Until explicit CARB regulations are in place, unmitigated GP 2020 emission inventories represent business-as-usual scenarios.
   - EIRs for GPs or RPs which demonstrate 2020 mitigated emissions are less than or equal to 1990 emissions are considered less than significant.

2. Demonstrate the Project is Exempt Based on SB 97

   - As specified in SB 97, projects that are funded under November 2006 Proposition 1B (Highway Safety, Traffic Reduction, Air Quality and Port Security Bond Act) and 1C (Disaster Preparedness and Flood Prevention Bond Act) may be exempt from analysis until January 1, 2010.



Jones & Stokes

Figure 1
Climate Change Significance Criteria Flow Chart

- An exemption can be used in an ND, MND, or EIR to support a less than significant finding for GHG impacts.

3. Demonstrate that the Project is on the 'Green List'

- This list would include projects that are deemed a positive contribution to California efforts to reduce GHG emissions. If the project is of the type described on the Green List it is considered less than significant.
- If the Green List entry description requires mitigation for impacts other than GHG, this methodology can be used in MNDs or EIRs; if the Green List entry does not require mitigation this methodology can be used in NDs, MNDs, or EIRs.

4. Demonstrate a Project's Compliance with a General Plan

- If a project is consistent with an appropriate General Plan's Greenhouse Gas Reduction Plan (GGRP), a project can be declared less than significant.
- Note that at this time there are no known jurisdictions that have a GGRP that has been fully subject to CEQA review. While Marin County has adopted a forward-thinking GGRP and it is described in the most recent GP update, the associated EIR does not analyze the secondary environmental impacts of some of the GGRP measures such as tidal energy. While one can reference GGRPs that have not been reviewed fully in CEQA, to attempt to show a project's compliance with such a plan as evidence that the project's GHG emission contributions are less than significant may not be supported by substantial evidence that cumulative emissions are being fully addressed in the particular jurisdiction.
- Compliance with a CEQA-vetted GGRP can be cited as evidence for all CEQA documents (Categorical Exemption, ND, MND, and EIR).

5. Analyze GHG Emissions and Mitigate using the Tiered Methodology

- Guidance and mitigation methodology for various development projects (residential, commercial, industrial) are listed in the form of tiered thresholds. If a project incorporates the mitigation measures specified in the tiered threshold tables the project is considered less than significant.
- All project emissions are considered less than significant if they are less than the threshold(s).
- If the tiered approach requires mitigation, this methodology can be used in MNDs or EIRs; if the tiered approach does not require mitigation this methodology can be used in NDs, MNDs, or EIRs.

The Green List

- The Green List would be a list of projects and project types that are deemed a positive contribution to California's efforts to reduce GHG emissions.
- If this approach is followed, it is suggested that CARB and the Attorney General (AG) are consulted prior to listing a project on the Green List to ensure consistency with CARB AB 32 efforts and to ensure that the Green List entries are consistent with how the AG office interprets AB 32 and GHG CEQA compliance.
- The Green List should be updated every 6 months or as major regulatory or legal developments unfold.
- Projects that are on the Green List are to be considered less than significant for GHG emissions purposes.
- A tentative list of potential Green List entries is presented below. Actual Green List entries should be far more specific and cover a broad range of project types and mitigation approaches. The list below is merely a proof-of-concept for the actual Green List.

1. Wind farm for the generation of wind-powered electricity
2. Extension of transit lines to currently developed but underserved communities
3. Development of high-density infill projects with easily accessible mass transit
4. Small hydroelectric power plants at existing facilities that generate 5 mw or less (as defined in Class 28 Categorical Exemption)
5. Cogeneration plants with a capacity of 50 mw or less at existing facilities (as defined in Class 29 Cat Exemption)
6. Increase in bus service or conversion to bus rapid transit service along an existing bus line
7. Projects with LEED "Platinum" rating
8. Expansion of recycling facilities within existing urban areas
9. Recycled water projects that reduce energy consumption related to water supplies that services existing development
10. Development of bicycle, pedestrian, or zero emission transportation infrastructure to serve existing regions

There are also several options for tiering and thresholds, as shown in Table 2 below. One could establish strictly numeric emissions thresholds and require mitigation to below the specific threshold to make a finding of less than significant. One could establish narrative emissions threshold that are based on a broader context of multiple approaches to GHG reductions and a presumption that projects of sufficiently low GHG intensity are less than significant.

In Concept 2A, a zero threshold would be applied to projects and thus only projects that result in a reduction of GHG emissions compared to baseline emissions would be less than significant absent mitigation. All projects would require quantified inventories. All projects that result in a net increase of GHG emissions would be required to mitigate their emissions to zero through direct mitigation or through fees or offsets or the impacts

Table 2: Approach 2 Tiering Options

	Concept 2A Zero	Concept 2B Quantitative	Concept 2C Qualitative
Tier 1	Project results in a net reduction of GHG emissions *Less than Significant*	Project in compliance with an AB 32-compliant General/Regional Plan, on the Green List, or below Tier 2 threshold. Level 1 Reductions (Could include such measures as: bike parking, transit stops for planned route, Energy Star roofs, Energy Star appliances, Title 24, water use efficiency, etc.) *Less than Significant*	Project in compliance with an AB 32-compliant General/Regional Plan, on the Green List, or below Tier 2 threshold. Level 1 Reductions (See measures under 2B) *Less than Significant*
Tier 2	Project results in net increase of GHG emissions Mitigation to zero (including offsets) *Mitigated to Less than Significant*	Above Tier 2 threshold Level 2 Mitigation (Could include such measures as: Parking reduction beyond code, solar roofs, LEED Silver or Gold Certification, exceed Title 24 by 20%, TDM measures, etc.) *Mitigated to Less than Significant*	Above Tier 2 threshold Level 2 Mitigation (See measures under 2B) *Mitigated to Less than Significant*
Tier 3	Mitigation infeasible to reduce emissions to zero (e.g., cost of offsets infeasible for project or offsets not available) *Significant and Unavoidable*	Above Tier 2 threshold With Level 1, 2 Mitigation Level 3 Mitigation: (Could include such measures as: On-site renewable energy systems, LEED Platinum certification, Exceed Title 24 by 40%, required recycled water use for irrigation, zero waste/high recycling requirements, mandatory transit passes, offsets/carbon impact fees) *Mitigated to Less than Significant*	Above Tier 3 thresholds Quantify Emissions, Level 3 Mitigation (see measures under 2B), and Offsets for 90% of remainder *Significance and Unavoidable*

would be identified as significant and unavoidable. This could be highly problematic and could eliminate the ability to use categorical exemptions and negative declarations for a wide range of projects.

In Concepts 2B and 2C, the first tier of a tiered threshold includes projects that are within a jurisdiction with an adopted greenhouse gas reduction plan (GGRP) and General Plan/Regional Plan that is consistent with AB 32 (and in line with S-3-05), or are on the Green List, or are below the Tier 2 threshold. All Tier 1 projects would be required to implement mandatory reductions required due to other legal authority (Level 1 reductions) such as AB 32, Title 24, or local policies and ordinances. With Level 1

reduction measures, qualifying Tier 1 projects would be considered less than significant without being required to demonstrate mitigation to zero.

In Concept 2B, the Tier 2 threshold would be quantitative, and quantified inventories would be required. Several quantitative threshold options are discussed below. A more comprehensive set of Level 2 mitigation would be required. If the project's emissions still exceed the Tier 2 threshold, an even more aggressive set of Level 3 mitigation measures would be required including offsets (when feasible) to reduce emissions below the Tier 2 threshold.

In Concept 2C, there would be two thresholds, a lower Tier 2 threshold (the "low bar") and a higher Tier 3 threshold (the "high bar"). The Tier 2 threshold would be the significance threshold for the purposes of CEQA and would be qualitative in terms of units (number of dwelling units, square feet of commercial space, etc.) or a per capita ratio. Projects above the Tier 2 threshold would be required to implement the comprehensive set of Level 2 mitigation. Projects below the Tier 2 threshold would not be required to quantify emissions or reductions. The Tier 3 threshold would be a threshold to distinguish the larger set of projects for which quantification of emissions would be required. Level 3 mitigation would be required and the project would be required to purchase offsets (when feasible) in the amount of 90 percent of the net emissions after application of Level 1 reductions and Level 2 and 3 mitigation. A variant on Concept 2C would be to require mandatory Level 3 mitigation without quantification and offsets.

Approach 2 Threshold Options

Seven threshold options were developed for this approach. The set of options are framed to capture different levels of new development in the CEQA process and thus allow different levels of mitigation. Options range from a zero first-tier threshold (Threshold 2.1) up to a threshold for GHG that would be equivalent to the capture level (i.e., number of units) of the current criteria pollutant thresholds used by some air districts (Threshold 2.4). The decision-based implementation approach discussed above could be used for any of these options. Table 3 below compares the results of each of the approaches discussed here.

Threshold 2.1: Zero First Tier Tiered Threshold.

This option would employ the decision tree concept and set the first tier cut-point at zero. The second tier cut-point could be one of the qualitative or quantitative thresholds discussed below. First-tier projects would be required to implement a list of very feasible and readily available mitigation measures.

Threshold 2.2: Quantitative Threshold Based on Market Capture

A single quantitative threshold was developed in order to ensure capture of 90 percent or more of likely future discretionary developments. The objective was to set the emission

threshold low enough to capture a substantial fraction of future residential and non-residential development that will be constructed to accommodate future statewide population and job growth, while setting the emission threshold high enough to exclude small development projects that will contribute a relatively small fraction of the cumulative statewide GHG emissions.

The quantitative threshold was created by using the following steps:

- Reviewing data from four diverse cities (Los Angeles in southern California and Pleasanton, Dublin, and Livermore in northern California) on pending applications for development.

- Determining the unit (dwelling unit or square feet) threshold that would capture approximately 90 percent of the residential units or office space in the pending application lists.

- Based on the data from the four cities, the thresholds selected were 50 residential units and 30,000 square feet of commercial space.

- The GHG emissions associated with 50 single-family residential units and 30,000 square feet of office were estimated and were found to be 900 metric tons and 800 metric tons, respectively. Given the variance on individual projects, a single threshold of 900 metric tons was selected for residential and office projects.

- A 900 metric ton threshold was also selected for non-office commercial projects and industrial projects to provide equivalency for different projects in other economic sectors.

- If this threshold is preferred, it is suggested that a more robust data set be examined to increase the representativeness of the selected thresholds. At a minimum, a diverse set of at least 20 cities and/or counties from throughout the state should be examined in order to support the market capture goals of this threshold. Further, an investigation of market capture may need to be conducted for different commercial project types and for industrial projects in order to examine whether multiple quantitative emissions thresholds or different thresholds should be developed.

The 900-ton threshold corresponds to 50 residential units, which corresponds to the 84th percentile of projects in the City of Los Angeles, the 79th percentile in the City of Pleasanton, the 50th percentile in the City of Livermore and the 4th percentile in the City of Dublin. This is suggestive that the GHG reduction burden will fall on larger projects that will be a relatively small portion of overall projects within more developed central cities (Los Angeles) and suburban areas of slow growth (Pleasanton) but would be the higher portion of projects within moderately (Livermore) or more rapidly developing areas (Dublin). These conclusions are suggestive but not conclusive due to the small sample size. The proposed threshold would exclude the smallest proposed developments

from potentially burdensome requirements to quantify and mitigate GHG emissions under CEQA. While this would exclude perhaps 10 percent of new residential development, the capture of 90 percent of new residential development would establish a strong basis for demonstrating that cumulative reductions are being achieved across the state. It can certainly serve as an interim measure and could be revised if subsequent regulatory action by CARB shows that a different level or different approach altogether is called for.

The 900-ton threshold would correspond to office projects of approximately 35,000 square feet, retail projects of approximately 11,000 square feet, or supermarket space of approximately 6,300 square feet. 35,000 square feet would correspond to the 46th percentile of commercial projects in the City of Los Angeles, the 54th percentile in the City of Livermore, and the 35th percentile in the City of Dublin. However, the commercial data was not separated into office, retail, supermarket or other types, and thus the amount of capture for different commercial project types is not known. The proposed threshold would exclude smaller offices, small retail (like auto-parts stores), and small supermarkets (like convenience stores) from potentially burdensome requirements to quantify and mitigate GHG emissions under CEQA but would include many medium-scale retail and supermarket projects.

The industrial sector is less amenable to a unit-based approach given the diversity of projects within this sector. One option would be to adopt a quantitative GHG emissions threshold (900 tons) for industrial projects equivalent to that for the residential/commercial thresholds described above. Industrial emissions can result from both stationary and mobile sources. CARB estimates that their suggested reporting threshold for stationary sources of 25,000 metric tons accounts for more than 90 percent of the industrial sector GHG emissions (see Threshold 2.3 for 25,000 metric ton discussion). If the CARB rationale holds, then a 900 metric ton threshold would likely capture at least 90 percent (and likely more) of new industrial and manufacturing sources. If this approach is advanced, we suggest further examination of industrial project data to determine market capture.

This threshold would require the vast majority of new development emission sources to quantify their GHG emissions, apportion the forecast emissions to relevant source categories, and develop GHG mitigation measures to reduce their emissions.

<u>Threshold 2.3: CARB Reporting Threshold</u>

CARB has recently proposed to require mandatory reporting from cement plants, oil refineries, hydrogen plants, electric generating facilities and electric retail providers, cogeneration facilities, and stationary combustion sources emitting $\geq$ 25,000 MT CO_2e/yr. AB 32 requires CARB to adopt a regulation to require the mandatory reporting and verification of emissions. CARB issued a preliminary draft version of its proposed reporting requirements in August 2007 and estimates that it would capture 94 percent of the GHG emissions associated with stationary sources.

This threshold would use 25,000 metric tons per year of GHG as the CEQA significance level. CARB proposed to use the 25,000 metric tons/year value as a reporting threshold, not as a CEQA significance threshold that would be used to define mitigation requirements. CARB is proposing the reporting threshold to begin to compile a statewide emission inventory, applicable only for a limited category of sources (large industrial facilities using fossil fuel combustion).

A 25,000 metric ton significance threshold would correspond to the GHG emissions of approximately 1,400 residential units, 1 million square feet of office space, 300,000 square feet of retail, and 175,000 square feet of supermarket space. This threshold would capture far less than half of new residential or commercial development.

As noted above, CARB estimates the industrial-based criteria would account for greater than 90 percent of GHG emissions emanating from stationary sources. However, industrial and manufacturing projects can also include substantial GHG emissions from mobile sources that are associated with the transportation of materials and delivery of products. When all transportation-related emissions are included, it is unknown what portion of new industrial or manufacturing projects a 25,000-ton threshold would actually capture.

An alternative would be to use a potential threshold of 10,000 metric tons considered by the Market Advisory Committee for inclusion in a Greenhouse Gas Cap and Trade System in California. A 10,000 metric ton significance threshold would correspond to the GHG emissions of approximately 550 residential units, 400,000 square feet of office space, 120,000 square feet of retail, and 70,000 square feet of supermarket space. This threshold would capture roughly half of new residential or commercial development.

Threshold 2.4: Regulated Emissions Inventory Capture

Most California air districts have developed CEQA significance thresholds for NOx and ROG emissions to try to reduce emissions of ozone precursors from proposed sources that are not subject to NSR pre-construction air quality permitting. The historical management of ozone nonattainment issues in urbanized air districts is somewhat analogous to today's concerns with greenhouse gas emissions in that regional ozone concentrations are a cumulative air quality problem caused by relatively small amounts of NOx and ROG emissions from thousands of individual sources, none of which emits enough by themselves to cause elevated ozone concentrations. Those same conditions apply to global climate change where the environmental problem is caused by emissions from a countless number of individual sources, none of which is large enough by itself to cause the problem. Because establishment of NOx/ROG emissions CEQA significance thresholds has been a well-tested mechanism to ensure that individual projects address cumulative impacts and to force individual projects to reduce emissions under CEQA, this threshold presumes the analogy of NOx/ROG emission thresholds could be used to develop similar GHG thresholds.

The steps to develop a GHG emission threshold based on the NOx/ROG analogy were as follows:

- For each agency, define its NOx/ROG CEQA thresholds.
- For each agency, define the regional NOx/ROG emission inventory the agency is trying to regulate with its NOx/ROG thresholds.
- For each agency, calculate the percentage of the total emission inventory for NOx represented by that agency's CEQA emission threshold. That value represents the "minimum percentage of regulated inventory" for NOx.
- The current (2004) California-wide GHG emission inventory is 499 million metric tons per year of CO_2 equivalent (MMT CO_2e). Apply the typical "minimum percentage of regulated inventory" value to the statewide GHG inventory, to develop a range of analogous GHG CEQA thresholds.

The preceding methodology was applied to two different air quality districts: the Bay Area Air Quality Management District (BAAQMD), a mostly-urbanized agency within which most emissions are generated from urban areas; and the San Joaquin Valley Air Pollution Control District (SJVAPCD), which oversees emissions emanating in part from rural areas that are generated at dispersed agricultural sources and area sources. For example, in the Bay Area the NOx threshold is 15 tons/year. The total NOx inventory for 2006 was 192,000 tons/year (525 tons/day). The threshold represents 0.008 percent of the total NOx inventory. Applying that ratio to the total statewide GHG emissions inventory of 499 MMT CO_2e (2004) yields an equivalent GHG threshold of 39,000 MMT CO_2e.

The range of analogous CEQA GHG thresholds derived from those two agencies is tightly clustered, ranging from 39,000 to 46,000 tons/year. A 39,000 to 46,000 metric ton threshold would correspond to the GHG emissions of approximately 2,200 to 2,600 residential units, 1.5 to 1.8 million square feet of office space, 470,000 to 560,000 square feet of retail, and 275,000 to 320,000 square feet of supermarket space. This threshold would capture far less than half of new residential or commercial development. Similarly, this threshold would capture less of new industrial/manufacturing GHG emissions inventory than Thresholds 2.2 or 2.3.

<u>Threshold 2.5: Unit-Based Thresholds Based on Market Capture</u>

Unit thresholds were developed for residential and commercial developments in order to capture approximately 90 percent of future development. The objective was to set the unit thresholds low enough to capture a substantial fraction of future housing and commercial developments that will be constructed to accommodate future statewide population and job growth, while setting the unit thresholds high enough to exclude small development projects that will contribute a relatively small fraction of the cumulative statewide GHG emissions. Sector-based thresholds were created by using the same steps

and data used to create Threshold 2.2- Quantitative Threshold Based on Market Capture above.

The distribution of pending application data suggests that the GHG reduction burden will fall on larger projects that will be a relatively small portion of overall projects within more developed central cities and suburban areas of slow growth but would be the higher portion of projects within moderately or rapidly developing areas. The proposed threshold would exclude the smallest proposed developments from potentially burdensome requirements to quantify and mitigate GHG emissions under CEQA. While this would exclude perhaps 10 percent of new residential development, the capture of 90 percent of new residential development would establish a strong basis for demonstrating that cumulative reductions are being achieved across the state. It can certainly serve as an interim measure and could be revised if subsequent regulatory action by CARB shows that a different level or different approach altogether is called for.

A similar rationale can be applied to the development of a commercial threshold. Threshold 2.5 would exclude many smaller businesses from potentially burdensome requirements to quantify and mitigate GHG emissions under CEQA. It should be noted that the GHG emissions of commercial projects vary substantially. For example, the carbon dioxide emissions associated with different commercial types were estimated as follows:

- 30,000 square-foot (SF) office = 800 metric tons/year CO_2
- 30,000 SF retail = 2,500 metric tons/year CO_2
- 30,000 SF supermarket = 4,300 metric tons/year CO_2

Thus, in order to assure appropriate market capture on an emissions inventory basis, it will be important to examine commercial project size by type, instead of in the aggregate (which has been done in this paper).

The industrial sector is less amenable to a unit-based approach given the diversity of projects within this sector. One option would be to use a quantitative threshold of 900 tons for industrial projects in order to provide for rough equivalency between different sectors. Industrial emissions can result from both stationary and mobile sources. However, if the CARB rationale for > 90 percent stationary source capture with a threshold of 25,000 metric tons holds, then a 900 metric ton threshold would likely capture at least 90 percent (and likely more) of new industrial sources. Further examination of unit-based industrial thresholds, such as the number of employees or manufacturing floor space or facility size, may provide support for a unit-based threshold based on market capture.

This threshold would require the vast majority of new development emission sources to quantify their GHG emissions, apportion the forecast emissions to relevant source categories, and develop GHG mitigation measures to reduce their emissions.

Threshold 2.6. Projects of Statewide, Regional, or Areawide Significance

For this threshold, a set of qualitative, tiered CEQA thresholds would be adopted based on the definitions of "projects with statewide, regional or areawide significance" under the Guidelines for California Environmental Quality Act, CCR Title 14, Division 6, Section 15206(b).

Project sizes defined under this guideline include the following:

- Proposed residential development of more than 500 dwelling units.
- Proposed shopping center or business establishment employing more than 1,000 persons or encompassing more than 500,000 square feet of floor space.
- Proposed commercial office building employing more than 1,000 persons or encompassing more than 250,000 square feet of floor space.
- Proposed hotel/motel development of more than 500 rooms.
- Proposed industrial, manufacturing or processing plant or industrial park planned to house more than 1,000 persons, or encompassing more than 600,000 square feet of floor space.

These thresholds would correspond to the GHG emissions of approximately 9,000 metric tons for residential projects, 13,000 metric tons for office projects, and 41,000 metric tons for retail projects. These thresholds would capture approximately half of new residential development and substantially less than half of new commercial development. It is unknown what portion of the new industrial or manufacturing GHG inventory would be captured by this approach.

Threshold 2.7 Efficiency-Based Thresholds

For this approach, thresholds would be based on measurements of efficiency. For planning efforts, the metric could be GHG emissions per capita or per job or some combination thereof. For projects, the metric could be GHG emission per housing unit or per square foot of commercial space. In theory, one could also develop metrics for GHG emissions per dollar of gross product to measure the efficiency of the economy.

This approach is attractive because it seeks to benchmark project GHG intensity against target levels of efficiency. The thresholds would need to be set such that there is reasonably foreseeable and sufficient reductions compared to business as usual to support meeting AB 32 and S-3-05 goals in time (in combination with command and control regulations). Because this approach would require substantial data and modeling to fully develop, this is a concept considered as a potential future threshold and not appropriate

for interim guidance in the short term. Thus, it is not evaluated in the screening evaluation in the next section.

Table 3 compares the results for each of the approaches.

Table 3: Comparison of Approach 2 Tiered Threshold Options

Threshold	GHG Emission Threshold (metric tons/year)	Future Development Captured by GHG Threshold
2.1: Zero Threshold	0 tons/year	All
2.2: Quantitative Threshold Based on Market Capture	~900 tons/year	Residential development > 50 dwelling units Office space > 36,000 ft^2 Retail space >11,000 ft^2 Supermarkets >6.300 ft^2 small, medium, large industrial
2.3: CARB GHG Mandatory Reporting Threshold OR Potential Cap and Trade Entry Level	25,000 metric tons/year OR 10,000 metric tons/year	Residential development >1,400 dwelling units OR 550 dwelling units Office space >1 million ft^2 OR 400,000 ft^2 Retail space >300,000 ft^2 OR 120,000 ft^2 Supermarkets >175,000 ft^2 OR 70,000 ft^2 medium/larger industrial
2.4: Regulated Inventory Capture	40,000 – 50,000 metric tons/year	Residential development >2,200 to 2,600 dwelling units Office space >1.5 to 1.8 million ft^2 Retail space >470,000 to 560,000 ft^2 Supermarkets >270,000 to 320,000 ft^2 medium/larger industrial
2.5: Unit-Based Threshold Based on Market Capture	Not applicable.	Residential development >50 dwelling units Commercial space >50,000 ft^2 > small, medium, large industrial (with GHG emissions > 900 tonsCO2e)
2.6: Projects of Statewide, Regional, or Areawide Significance	Not applicable.	Residential development >500 dwelling units Office space >250,000 ft^2 Retail space >500,000 ft^2 Hotels >500 units Industrial project >1,000 employees Industrial project >40 acre or 650,000 ft^2
2.7: Efficiency-Based Thresholds	TBD tons/year/person TBD tons/year/unit	Depends on the efficiency measure selected.

Implementing CEQA With Tiered Thresholds

Several issues related to Approach 2 are addressed below:

1. *Some applications of this approach may need to be embodied in a duly approved General Plan, or in some other formal regulation or ordinance to be fully enforceable.* Because CEQA does not expressly provide that projects may be deemed insignificant based on implementation of a set of mitigations, this approach may need to be supported with specific and enforceable mechanisms adopted with due public process.

2. *How would this concept affect adoption of air district rules and regulations?* Proposed air district rules and regulations may be subject to CEQA like other projects and plans. Thus, if significance thresholds were adopted by an APCD or AQMD, then they could also apply to air district discretionary actions. If GHG emissions would be increased by a rule or regulation for another regulated pollutant, that would be a potential issue for review under CEQA.

3. *Mitigation measures may not be all-inclusive; better measures now or new future technology would make these measures obsolete.* The mandatory mitigation measures could be periodically updated to reflect current technology, feasibility, and efficiency.

4. *Total reduction may not be quantified or difficult to quantify.* CEQA only requires the adoption of feasible mitigation and thus the reduction effectiveness of required mitigation should not be in question. However, the precise reduction effectiveness may indeed be difficult to identify. As described above, if a quantitative threshold is selected as the measure of how much mitigation is mandated, then best available evidence will need to be used to estimate resultant GHG emissions with mitigation adoption. If a qualitative threshold is selected, then it may not be necessary to quantify reductions.

5. *Difficult to measure progress toward legislative program goals.* One could require reporting of project inventories to the Climate Action Registry, air district, or regional council of governments, or other suitable body. Collection of such data would allow estimates of the GHG intensity of new development over time, which could be used by CARB to monitor progress toward AB 32 goals.

6. *Measures may have adverse impacts on other programs.* The identification of mandatory mitigation will need to consider secondary environmental impacts, including those to air quality.

7. *Consideration of life-cycle emissions.* In many cases, only direct and indirect emissions may be addressed, rather than life-cycle emissions. A project applicant has traditionally been expected to only address emissions that are closely related and within the capacity of the project to control and/or influence. The long chain

8. of economic production resulting in materials manufacture, for example, involves numerous parties, each of which in turn is responsible for the GHG emissions associated with their particular activity. However, there are situations where a lead agency could reasonably determine that a larger set of upstream and downstream emissions should be considered because they are being caused by the project and feasible alternatives and mitigation measures may exist to lessen this impact.

Approach 2 Tiered Threshold with Mandatory Mitigation

As shown in Table 2, due to the cumulative nature of GHG emissions and climate change impacts, there could be a level of mandatory reductions and/or mitigation for all projects integrated into a tiered threshold approach. In order to meet AB 32 mandates by 2020 and S-3-05 goals, there will need to be adoption of GHG reduction measures across a large portion of the existing economy and new development. As such, in an effort to support a determination under CEQA that a project has a less than considerable contribution to significant cumulative GHG emissions, mitigation could be required on a progressively more comprehensive basis depending on the level of emissions.

- Level 1 Reductions – These reduction measures would apply to all projects and would only consist of AB 32 and other local/state mandates. They would be applied to a project from other legal authority (not CEQA). Level 1 reductions could include such measures as bike parking, transit stops for planned routes, Energy Star roofs, Energy Star appliances, Title 24 compliance, water use efficiency, and other measures. All measures would have to be mandated by CARB or local regulations and ordinances.

- Level 2 Mitigation – Projects that exceed the determined threshold would be required to first implement readily available technologies and methodologies with widespread availability. Level 2 Mitigation could include such measures as: parking reduction below code minimum levels, solar roofs, LEED Silver or Gold Certification, exceed Title 24 building standards by 20 percent, Traffic Demand Management (TDM) measures, and other requirements.

- Level 3 Mitigation - If necessary to reduce emissions to the thresholds, more extensive mitigation measures that represent the top tier of feasible efficiency design would also be required. Level 3 Mitigation could include such measures as: on-site renewable energy systems, LEED Platinum certification, exceed Title 24 building requirements by 40 percent, required recycled water use for irrigation, zero waste/high recycling requirements, mandatory transit pass provision, and other measures.

- Offset Mitigation – If, after adoption of all feasible on-site mitigation, the project is still found to exceed a Tier 2 quantitative threshold, or exceed a Tier 3 qualitative threshold, or if a project cannot feasibly implement the mandatory on-site mitigation, then purchases of offsets could be used for mitigation. In the case

of a quantitative threshold, the amount of purchase would be to offset below the Tier 2 significance threshold. In the case of a qualitative threshold, the amount of purchase could be to offset GHG emissions overall to below the lowest equivalent GHG emissions among the Tier 2 qualitative thresholds. With Threshold 2.5, this would be approximately 900 tons of GHG emissions (corresponding to 50 residential units). With Threshold 2.6, this would be approximately 9,000 tons (corresponding to 500 residential units). Alternatively, one could require purchase of offsets in the amount of a set percentage (such as 90% or 50% for example) of the residual GHG emissions (after other mitigation). As discussed earlier, any decision to include or require the use of emission reduction credits (or offsets) must consider issues of availability, quality, and environmental justice.

Substantial Evidence Supporting Different Thresholds

If a project can be shown by substantial evidence not to increase GHG emissions relative to baseline emissions, then no fair argument will be available that the project contributes considerably to a significant cumulative climate change impact.

It is more challenging to show that a project that increases GHG emissions above baseline emissions does not contribute considerably to a significant cumulative climate change impact. It is critical therefore, to establish an appropriate cumulative context, in which, although an individual project may increase GHG emissions, broader efforts will result in net GHG reductions.

Approach 1-based thresholds that by default will require an equal level of GHG reductions from the existing economy (Thresholds 1.1, 1.3, and 1.4) may be less supportable in the short run (especially before 2012) than Approach 1.2 (which requires new development to be relatively more efficient than a retrofitted existing economy). This is because, prior to 2012, there will only be limited mandatory regulations implementing AB 32 that could address the existing economy in a truly systematic way that can be relied upon to demonstrate that overall GHG reduction goals can be achieved by 2020. Approach 1.2 will still rely on substantial reductions in the existing economy but to a lesser degree.

Approach 1-based thresholds that would spread the mitigation burden across a sector (Threshold 1.3) or across a region (Threshold 1.4) will allow for tradeoffs between projects or even between municipalities. In order to demonstrate that a sector or a region is achieving net reductions overall, there would need to be feasible, funded, and mandatory requirements in place promoting an overall reduction scheme, in order for a project to result in nominal net increased GHG emissions.

Approach 2-based thresholds that capture larger portions of the new development GHG inventory (Thresholds 2.2 and 2.5) would promote growth that results in a smaller increase in GHG emissions; they may therefore be more supportable than thresholds that do not and that have a greater reliance on reductions in the existing economy (Thresholds

2.3, 2.4, and 2.6), especially in the next three to five years. With an established cumulative context that demonstrates overall net reductions, all threshold approaches could be effective in ensuring growth and development that significantly mitigates GHG emissions growth in a manner that will allow the CARB to achieve the emission reductions necessary to meet AB 32 targets. In that respect, all of these thresholds are supported by substantial evidence.

Evaluation of Non-Zero Threshold Options

Overarching issues concerning threshold development are reviewed below. Where appropriate, different features or application of the two conceptual approaches and the various options for thresholds under each conceptual approach described above are analyzed. The screening evaluation is summarized in Tables 4 (Approach 1) and 5 (Approach 2). The summary tables rate each threshold for the issues discussed below based on the level of confidence (low, medium or high) ascribed by J&S. The confidence levels relate to whether a threshold could achieve a particular attribute, such as emission reduction effectiveness. For example, a low emission reduction effectiveness rating means the threshold is not expected to capture a relatively large portion of the new development inventory.

As described above, Threshold 2.7 is not included in this evaluation because the data to develop an efficiency-based threshold has not been reviewed at this time and because this threshold is not considered feasible as an interim approach until more detailed inventory information is available across the California economy.

<u>What is the GHG Emissions Effectiveness of Different Thresholds?</u>

Effectiveness was evaluated in terms of whether a threshold would capture a large portion of the GHG emissions inventory and thus require mitigation under CEQA to control such emissions within the larger framework of AB 32. In addition, effectiveness was also evaluated in terms of whether a threshold would require relatively more or less GHG emissions reductions from the existing economy verses new development. This is presumptive that gains from the existing economy (through retrofits, etc.) will be more difficult and inefficient relative to requirements for new development.

Approach 1-based thresholds that require equivalent reductions relative to business-as-usual (Thresholds 1.1, 1.3, and 1.4) for both the existing and new economy will be less effective than thresholds that support lower-GHG intensity new development (Approach 1.2). However, since Approach 1-based thresholds do not establish a quantitative threshold below which projects do not have to mitigate, the market capture for new development is complete.

Approach 2-based thresholds can be more or less effective at capturing substantial portions of the GHG inventory associated with new development depending on where the quantitative or qualitative thresholds are set. Lower thresholds will capture a broader range of projects and result in greater mitigation. Based on the review of project data for

the select municipalities described in the Approach 2 section above, thresholds based on the CARB Reporting Threshold/Cap and Trade Entry Level (Threshold 2.4) or CEQA definitions of "Statewide, Regional or Areawide" projects (Threshold 2.6) will result in a limited capture of the GHG inventory. Lower quantitative or qualitative thresholds (Thresholds 2.1, 2.2 and 2.5) could result in capture of greater than 90 percent of new development.

Are the Different Thresholds Consistent with AB 32 and S-3-05?

Thresholds that require reductions compared to business-as-usual for all projects or for a large portion of new development would be consistent with regulatory mandates. In time, the required reductions will need to be adjusted from 2020 (AB 32) to 2050 (S-3-05) horizons, but conceptually broad identification of significance for projects would be consistent with both of these mandates. Thresholds that exclude a substantial portion of new development would likely not be consistent, unless it could be shown that other more effective means of GHG reductions have already been, or will be adopted, within a defined timeframe.

All Approach 1-based thresholds would be consistent with AB 32 and S-3-05 if it can be demonstrated that other regulations and programs are effective in achieving the necessary GHG reduction from the existing economy to meet the overall state goals.

Approach 2-based thresholds that include substantive parts of the new development GHG inventory (Thresholds 2.1, 2.2 and 2.5) will be more consistent with AB 32 and S-3-05 than those that do not (Thresholds 2.3, 2.4, and 2.6) unless it can be demonstrated that other regulations and programs are effective in achieving the necessary GHG reduction from the existing economy to meet the overall state goals.

What are the Uncertainties Associated with Different Thresholds?

All thresholds have medium to high uncertainties associated with them due to the uncertainty associated with the effectiveness of AB 32 implementation overall, the new character of GHG reduction strategies on a project basis, the immaturity of GHG reduction technologies or infrastructure (such as widespread biodiesel availability), and the uncertainty of GHG reduction effectiveness of certain technologies (such as scientific debate concerning the relative lifecycle GHG emissions of certain biofuels, for example).

In general, Approach 1-based thresholds have higher uncertainties than Approach 2 thresholds because they rely on a constantly changing definition of business-as-usual. Threshold 1.2, with its relatively smaller reliance on the existing economy for GHG reductions has relatively less uncertainty than other Approach 1 thresholds. Thresholds that spread mitigation more broadly (Thresholds 1.3 and 1.4) have less uncertainty by avoiding the need for every project to mitigate equally.

Approach 2 thresholds with lower quantitative (2.1 and 2.2) or qualitative (2.5) thresholds will have uncertainties associated with the ability to achieve GHG reductions

from small to medium projects. Approach 2 thresholds with higher quantitative (2.3, 2.4) or qualitative (2.6) thresholds will have uncertainties associated with the ability to achieve relatively larger GHG reductions from the existing economy.

What are Other Advantages/Disadvantages of the Different Thresholds?

Thresholds with a single project metric (Thresholds 1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, and 2.6) will be easier to apply to individual projects and more easily understood by project applicants and lead agencies broadly. Thresholds that spread mitigation across sectors (1.3) or regions (1.4), while simple in concept, will require adoption of more complicated cross-jurisdictional reduction plans or evaluation of broad sector-based trends in GHG intensity reduction over time. Approach 1 options would require all projects to quantify emissions in order to determine needed reductions relative to business-as-usual (which will change over time as described above). Concepts that are unit-based (Threshold 2.5 and 2.6) will not result in thresholds that have equal amount of GHG emissions, and thus equity issues may arise.