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MICRO-OFFSETS AND MACRO-TRANSFORMATION: AN INCONVENIENT VIEW OF CLIMATE CHANGE JUSTICE

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We have been asked to examine climate change justice by discussing the methods of allocating the costs of addressing climate change among nations. Our analysis suggests that climate and justice goals cannot be achieved by better allocating the emissions reduction burdens of current carbon mitigation proposals — there may be no allocation of burdens using current approaches that achieves both climate and justice goals. Instead, achieving just the climate goal without exacerbating justice concerns, much less improving global justice, will require focusing on increasing well-being and inducing fundamental changes in development patterns to generate greater levels of well-being with reduced levels of material throughput. We identify several core characteristics of the public and private policy architectures and initiatives necessary to accomplish this task. We also propose examples of short- and long-term initiatives. Our near-term approach recognizes that a focus on public law remedies and nation-states is necessary but not sufficient. We suggest a feasible new mechanism, equity micro-offsets, that could reduce emissions while improving well-being among the poor. Equity micro-offsets can harness altruistic preferences, market mechanisms, and private oversight to reduce emissions and increase well-being in poor countries. Equity micro-offsets also suggest the nature of the long-term political, social, and economic macro-transformation that may be necessary. From household cook stove initiatives to policy architectures that include forestry, agriculture, and other overlooked sectors, achieving climate and justice goals will require transformative approaches, not just improved cost allocations.

INTRODUCTION

As any professor knows, when confronted with a hard problem, the first tendency of many students is to make assumptions that cause the problem to disappear. Too many modern approaches to climate justice take this approach. They either assume away the climate goal or the justice goal, or they implicitly concede that these goals will not be achieved at all, or will only be achieved with radical technological advances or other heroic developments. In some cases they do so in transparent ways. In other cases, they do so through opaque assumptions in mathematical models. By avoiding the hard truth about the depth of the problem, these approaches delay development of the deep structural changes necessary to reduce the risk of catastrophic climate change.

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Scholars have offered a number of thoughtful examinations of the deontological and welfarist reasons to achieve climate and justice goals, and we do not re-plow that ground in this Article.[1] Instead, we assume that policymakers should seek to achieve a substantial reduction in the risks of catastrophic climate change and to improve the welfare of the poor around the globe.[2] We also assume that achieving any meaningful climate goal will require a post-Kyoto agreement that all major emitting nations join in and comply with over time.[3] For the major players to join in the agreement, they must view it to be in their interest, accounting for the cost of greenhouse gas ("GHG") emissions reductions, the avoided cost of climate change, the impacts on justice, and other concerns.

On the surface, many economic analyses and proposals by governments and non-governmental organizations ("NGOs") offer optimistic views and policy architectures.[4] They suggest that climate goals can be achieved with small percentage reductions in global world product ("GWP") or gross domestic product ("GDP"). They offer a variety of ways to induce participation by developing countries and to address justice issues, often through reduced or delayed emissions reduction burdens for developing countries that will enable substantial per capita income growth in those countries.[5] Drawing on recent developments in the economics and climate science liter-

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[1] *See, e.g.*, Eric A. Posner & Cass R. Sunstein, *Climate Change Justice*, 96 GEO. L.J. 1565, 1611–12 (2008); Daniel A. Farber, *The Moral Case for Climate Compensation: Doing Justice in a Complex World*, 2008 UTAH L. REV. 377; Matthew D. Adler, *Corrective Justice and Liability for Global Warming*, 155 U. PA. L. REV. 1859, 1861–62 (2007). Climate justice issues arise in several ways. *See* Michael P. Vandenbergh & Brooke A. Ackerly, *Climate Change: The Equity Problem*, 26 VA. ENVTL. L.J. 55, 75–76 (2007) (noting that the costs of climate change and climate change mitigation are likely to be inequitably distributed); Brooke Ackerly & Michael P. Vandenbergh, *Climate Change Justice: The Challenge for Global Governance*, 20 GEO. INT'L ENVTL. L. REV. 553, 555–56 (2008) (noting the global justice concern associated with the ceiling on economic activity that may occur because of carbon constraints).

[2] *See* Joseph E. Aldy & Robert N. Stavins, Designing the Post-Kyoto Climate Regime: Lessons from the Harvard Project on International Climate Agreements (Nov. 24, 2008) (unpublished interim report), *available at* http://belfercenter.ksg.harvard.edu/files/Interim%20Report%20081203%20Akiko%20v6.pdf (identifying principles).

[3] *See* Cass R. Sunstein, *The World vs. the United States and China? The Complex Climate Change Incentives of the Leading Greenhouse Gas Emitters*, 55 UCLA L. REV. 1675, 1676 (2008); Jonathan B. Wiener, *Climate Change Policy and Policy Change in China*, 55 UCLA L. REV. 1805, 1823–24 (2008); SCOTT BARRETT, WHY COOPERATE?: THE INCENTIVE TO SUPPLY GLOBAL PUBLIC GOODS 93, 162–64 (2007) (discussing importance of incentives).

[4] *See, e.g.*, Valentina Bosetti et al., *Modeling Economic Impacts of Alternative International Climate Policy Architectures: A Quantitative and Comparative Assessment of Architectures for Agreement* (Harvard Project on Int'l Climate Agreements, Discussion Paper 08-20, 2008), *available at* http://belfercenter.ksg.harvard.edu/files/CarraroWeb3.pdf (examining eight "policy architectures").

[5] *See, e.g.*, Jing Cao, *Reconciling Human Development and Climate Protection: Perspectives from Developing Countries on Post-2012 International Climate Change Policy* (Harvard Project on Int'l Climate Agreements, Discussion Paper 08-25, 2008), *available at* http://belfer center.ksg.harvard.edu/files/CaoWeb2.pdf (proposing allocation that allows substantial growth in per capita income in developing countries); Jeffrey Frankel, *An Elaborated Proposal For Global Climate Policy Architecture: Specific Formulas and Emission Targets for All Countries in All Decades* (Harvard Project on Int'l Climate Agreements, Discussion Paper 08-08, 2008), *available at* http://ksghome.harvard.edu/~jfrankel/SpecificTargets2008HPICA.pdf (proposing

atures, we examine the intuitive plausibility of these approaches. We conclude that although on the surface a number of proposed policy architectures are politically viable, address justice issues, and have reasonably low mitigation costs, upon closer inspection they rest on implausible assumptions and avoid many hard questions.

The most important assumption in proposed policy architectures is that they will achieve an adequate reduction in the risk of catastrophic climate change. Numerous governmental and private entities have articulated a goal of achieving the emissions reductions necessary to limit temperature increases to 2 degrees Celsius ("°C") over pre-industrial era levels,[6] a target that will require stabilization of atmospheric concentrations of carbon dioxide equivalents ("CO_2eq") at roughly 450 ppm.[7] Even at 450 ppm CO_2eq, there is still a substantial risk of higher temperatures, including temperatures that could lead to catastrophic climate change.[8] Thus, even at 450 ppm CO_2eq the likelihood of catastrophic climate change is far greater than the likelihood that your house will burn down.[9] Unfortunately, many proposed architectures do not purport to achieve atmospheric concentrations in the 450 ppm CO_2eq range and thus have little prospect of achieving the 2°C target.[10] Some will achieve temperature increases closer to 3°C, and others will not even do that.[11] The implicit assumption in these proposals is that it is acceptable to miss the widely adopted target. This assumption may be

allocation that allows business as usual emissions for developing countries for decades before requiring reductions).

[6] *See* discussion *infra* notes 56, 92–96, and accompanying text.

[7] Assessments of the atmospheric concentration of CO_2 or CO_2eq necessary to achieve stabilization at 2°C vary, but the 450 ppm CO_2eq level is supported by a number of sources. *See, e.g.*, INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE ("IPCC"), CONTRIBUTION OF WORKING GROUP III TO THE FOURTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: MITIGATION 39 tbl.TS.2 (2007) [hereinafter IPCC AR4 WG III], *available at* http://www.ipcc.ch/ipccreports/ar4-wg3.htm (noting that the Category I emissions scenario generates a CO_2eq atmospheric concentration range of 445 to 490 ppm, which is associated with a temperature range of 2.0 to 2.4°C); Nicholas Stern, *The Economics of Climate Change*, 98 AM. ECON. REV. (PAPERS & PROC.) 1, 5 tbl.1 (2008) (noting a 78% likelihood of exceeding a 2°C increase at 450 ppm CO_2eq); ROSS GARNAUT, THE GARNAUT CLIMATE CHANGE REVIEW 192–94 (2008), *available at* http://www.garnautreview.org.au/index.htm (follow link for PDF of full report) (discussing various temperature and atmospheric concentration targets). CO_2 is the GHG responsible for more than 80% of anthropogenic radiative forcing, and CO_2eq is the combination of the six most important greenhouse gases. IPCC, CONTRIBUTION OF WORKING GROUP I TO THE FOURTH ASSESSMENT REPORT OF THE IPCC, CLIMATE CHANGE 2007: THE PHYSICAL BASIS 210–16 (2007) [hereinafter IPCC AR4 WG I], *available at* http://www.ipcc.ch/ipccreports/ar4-wg1.htm.

[8] *See* Stern, *supra* note 7, at 5 tbl.1 (noting that at 450 ppm CO_2eq there is an 18% likelihood of a 3°C temperature increase, a 3% likelihood of a 4°C increase, and a 1% likelihood of a 5°C increase).

[9] *See, e.g.*, Martin L. Weitzman, *On Modeling and Interpreting the Economics of Catastrophic Climate Change*, 91 REV. ECON. & STAT. 1, 18 (2009) (noting that "[o]ne might try to compare numbers on, say, a homeowner buying fire insurance . . . with cost-benefit estimates of the world buying an insurance policy going some way toward mitigating the extreme high-temperature possibilities"); *see also infra* notes 70–75 (discussing likelihood of catastrophic climate change).

[10] *See* Bosetti et al., *supra* note 4, at 11 fig.3.

[11] *Id.*

rational based on one's risk tolerance. Climate sensitivity may be less than current models suggest, or the costs of the necessary emissions reductions may be greater than the harms of catastrophic climate change. But unless the likelihood that these architectures will miss the 2°C mark is clear, it will be difficult for policymakers to develop and weigh options that achieve that goal. In addition, even policy architectures that are designed to achieve temperature changes well above 2°C rely on aggressive assumptions about the deployment of new and existing technologies, as well as perfect markets and policy implementation.[12]

The use of aggressive assumptions is fueled by the magnitude of the task. For example, even to achieve a global GHG target of roughly 650 ppm CO_2eq (a target far above the 450 ppm CO_2eq target associated with the 2°C goal) by using nuclear power alone would require the addition of a new, standard-sized (1000 megawatt) nuclear power plant every day for the next fifty years, in addition to substantial increases in efficiency and conservation.[13] To achieve a 650 ppm CO_2eq target with solar power would require installing twenty-seven square kilometers of solar cells every day over that period.[14]

The assumptions regarding developing country incentives are similarly aggressive. Many policy architectures assume that developing countries can be induced to participate by allowing substantial emissions growth and per capita income growth in those countries.[15] Essentially, developing countries are encouraged to develop and lock in a fossil fuel-driven industrialized society for decades before strong incentives push them to make the same transition that developed countries must make in the near future. Yet, to achieve an atmospheric GHG target of 450 ppm CO_2eq, global per capita GHG emissions in 2050 need to be at roughly the current level of India (two metric tons of CO_2eq), a level that is one-tenth of the United States (over twenty

[12] *See* discussion *infra* notes 86–110 and accompanying text; *see also* Stern, *supra* note 7, at 23.

[13] *See* Nathan S. Lewis, Professor, Cal. Inst. of Tech., Talk: Chemical Challenges in Renewable Energy 2–8 (transcript available at http://nsl.caltech.edu/files/energy_notes.pdf). Lewis's global energy demand estimate for 2050 of twenty-eight terawatts ("TW") assumes substantial demand-side energy efficiency and conservation efforts. *See id.* at 5. Lewis notes that "stabiliz[ing] at 550 ppm CO_2 would require ≈20 TW of carbon-free power." *Id.* at 7. The nuclear 20 TW calculation is 20,000 plants (up from 400 today), each with 1000 megawatt ("MW") capacity, installed over a period of fifty years. *See id.* at 7–8. Lewis's estimate of 550 ppm CO_2 is roughly equivalent to 650 ppm CO_2eq, based on the Category IV stabilization range. *See* IPCC AR4 WG III, *supra* note 7, at 39 tbl.TS.2.

[14] Lewis, *supra* note 13, at 12. Lewis notes that producing 20 TW of power from solar energy, assuming 10% conversion efficiency, would require covering "0.16% of the earth's surface, or $5x10^{11}$ m^2" with panels. *Id.* To achieve this capacity in 50 years would require installing 27,400,000 m^2 of panels per day. Note that producing 3 TW in the United States would require 1.7% of the country's land, and "covering every home rooftop in the entire U.S. would generate only 0.25 TW of power." *Id.*

[15] *See* discussion *infra* notes 20–22 and accompanying text; *see also* Frankel, *supra* note 5, at 7.

tons) and less than one-half of China (over five tons).[16] If per capita income growth is to be the vehicle for inducing developing countries to participate in a global agreement, it must occur with little or no per capita emissions growth for many developing countries, and substantial net declines for others.

The justice issue further complicates the task. We began our research with the assumption that a deep tension exists between the climate and justice goals, but our analysis suggests that just achieving the climate goal alone cannot occur without progress toward global justice. At the outset, it is hard to imagine overall improvements in the welfare of the poor in a world undergoing catastrophic climate change.[17] Further, a pure GHG strategy that does not account for justice concerns will not achieve the participation of the major developing countries that are essential to meeting atmospheric GHG targets.[18] Finally, a GHG strategy that does not account for the relationship between poverty alleviation and GHG emissions will overlook important emissions reductions,[19] and may even induce lifestyle changes that could increase emissions, further undermining the ability to achieve GHG targets. The framing of the climate justice issue as a matter of global income inequality constrains the set of proposed solutions to an untenable subset. If global justice requires ameliorating global income inequality by raising people out of poverty,[20] and poverty alleviation is synonymous with improvements in the per capita income of people in poverty,[21] and carbon emissions are closely associated with per capita income, then simply increasing per capita income is likely to make it very hard to achieve GHG emission reduction targets.[22]

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[16] *See* discussion *infra* notes 110–11 and accompanying text. Per capita CO_2eq emissions are based on data for 2005 from World Resources Institute, Climate Analysis Indicators Tool (CAIT) version 6.0 (2009), *available at* http://cait.wri.org/cait.php?page=yearly&mode=view.

[17] *See* Miles R. Allen & David J. Frame, *Call off the Quest*, 318 SCIENCE 582, 582 (2007) (noting that "[o]nce the world has warmed by 4 [degrees] C, conditions will be so different from anything we can observe today . . . that it is inherently hard to say when the warming will stop"); RICHARD POSNER, CATASTROPHE: RISK AND RESPONSE 46, 197 (2004) (discussing the challenges posed by abrupt climate change). Although improvements in other aspects of life (e.g., disease reduction, increases in consumer goods) achieved through allocations of resources to areas other than emissions reductions may enhance welfare, truly catastrophic climate change would make these other welfare-enhancing developments difficult to achieve.

[18] *See* Eric A. Posner & Cass R. Sunstein, *Should Greenhouse Gas Permits Be Allocated on a Per Capita Basis?*, 97 CAL. L. REV. 51 (2009) [hereinafter Posner & Sunstein, *Per Capita*]; Eric A. Posner & Cass R. Sunstein, *Global Warming and Social Justice*, REGULATION, Spring 2008, at 14, 17–20 [hereinafter Posner & Sunstein, *Social Justice*].

[19] *See* Ackerly & Vandenbergh, *supra* note 1, at 554.

[20] UNITED NATIONS, THE MILLENNIUM DEVELOPMENT GOALS REPORT 5 (2008), *available at* http://www.un.org/millenniumgoals/pdf/The%20Millennium%20Development%20Goals%20Report%202008.pdf (noting the "multiple dimensions of poverty").

[21] *See, e.g.*, Jing Cao, *supra* note 5, at 14 (adjusting emissions allocations to account for personal incomes).

[22] *See* Michael P. Vandenbergh, *Climate Change: The China Problem*, 81 S. CAL. L. REV. 905, 919 (2008) (discussing research on the Kuznets Curve and GHG emissions).

We suggest that greater attention should be directed toward developing policy architectures and initiatives that can improve the well-being of people in poverty in ways that also reduce carbon emissions. We call the political, social, and economic changes necessary to alleviate poverty while reducing GHG emissions "macro-transformation." We do not know precisely how this macro-transformation can or will take place, and we are not naïve about the magnitude of the task, but we argue that the debate should begin now. It should not be delayed until the unrealistic assumptions underlying the current climate change policy architecture proposals become apparent.

We assume that macro-transformation will require architectures that provide incentives for developing countries to transition directly from pre-industrial or semi-industrial to post-industrial societies, leap-frogging fossil fuel-based industrialization. Achieving macro-transformation will require substantial modifications to global and national public and private climate change governance schemes, and will require integration of GHG emissions reductions goals into many policies and institutions that are now unaffected by GHG considerations, particularly those focused on development. We also assume that macro-transformation will require policy architectures and initiatives that alleviate poverty by improving well-being, not just by increasing per capita incomes. We believe there is reason for optimism in the robust literature in economics and other fields that suggests that improvements in well-being can be achieved not just through increases in per capita income, but through changes in other aspects of life less closely correlated with GHG emissions, such as maternal and child survival, health, education, and access to safe water.[23] We also believe that recent initiatives focused on households, forests, and agriculture in developed and developing countries identify the types of paths that more widespread transformation may take.

In short, this frank truth is lurking too far beneath the surface of climate justice debates: no plausible collection of conventional initiatives, whether emissions allocations, compliance deadlines, or feasible side payments, is likely to induce the major emitting countries to participate in an international agreement that will achieve the temperature targets necessary to substantially reduce the risk of catastrophic climate change. By making assumptions about a more lenient temperature target, technological and other developments, and the ability to address poverty through per capita income increases, too many proposed approaches fail to address the hardest question: are these measures enough? The tendency to avoid this hard question is understandable. Those who worry most about climate may be willing to set unrealistic targets or use other unrealistic assumptions to avoid undermining public support. Those who worry most about the economic costs of mitigation or are skeptical of climate science may be willing to do the same to ensure that mitigation costs are low. Those who worry most about the poor may be willing to do the same to maximize the chance that governments will adopt policies that alleviate poverty.

[23] *See* discussion *infra* notes 154–58 and accompanying text.

It is possible that a lenient temperature target combined with optimistic technology, poverty alleviation, and other assumptions will lead to a successful resolution of the global political impasse. Parties may begin to take actions they would not otherwise take, resulting in patterns of behavior that facilitate future international agreements, domestic policies, and private market responses. But there is a tremendous opportunity cost. The time spent designing policy architectures and initiatives that may require future modification could instead be spent designing architectures and initiatives that are more likely to achieve the climate change goal. If we confront the problem head-on, it might be possible to achieve the climate and justice goals through adding new types of short-term measures that buy time on the climate front (e.g., equity micro-offsets) and to foster a longer term re-conceptualization of emissions reduction methods (macro-transformation). When combined with global public governance schemes such as cap-and-trade programs and carbon taxes, as well as major technological developments, these political, social, and economic transformations may increase the prospects that developed and developing countries will view steep emissions reductions as in their interest, and may enable aggressive emissions targets to be achieved, not assumed away.

We present our analysis in two Parts. In Part I, we examine the plausibility of achieving a viable climate solution with the current proposed policy architectures. We identify substantial doubts that they will achieve widely accepted temperature targets. In Part II, we identify several core characteristics of more transformative approaches. We also propose equity micro-offsets as one near-term climate change response that will use private markets to harness altruistic and climate norms to generate emissions reductions and increased welfare among the world's poor. Equity micro-offsets are GHG offsets generated by funding actions that reduce emissions from individuals who are at or below the poverty level. We also identify the contours of the macro-transformation that may be necessary by providing examples of existing public and private initiatives that integrate climate and justice goals by design.

I. Proposed Global Climate Architectures

Our first point is that achieving climate and justice goals will be very difficult with conventional policy architectures and initiatives. By policy architectures, we mean the high-level allocations of benefits and burdens in any international treaty or other public governance scheme.[24] An example is

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[24] *See generally* Bosetti et al., *supra* note 4. David Victor points out that the ultimate resolution may involve a collection of regional agreements with limited connections. *See* David G. Victor, *Fragmented Carbon Markets and Reluctant Nations: Implications for the Design of Effective Architectures*, *in* Architectures for Agreement: Addressing Global Climate Change in the Post-Kyoto World 133 (Joseph E. Aldy & Robert N. Stavins eds., 2007).

a global cap-and-trade scheme along with the accompanying allocation of emissions and compliance deadlines. By climate change policy initiatives, we mean the specific steps that are likely to be conducted pursuant to the policy architecture. Examples include a GHG tailpipe standard for cars, a renewable energy requirement for electric utilities, or a requirement for carbon capture and storage. We focus principally on policy architectures in this Part.

The hard questions regarding climate justice are difficult to confront in part because numerous variables and inconsistent terminology make it a challenge to analyze policy architectures and to identify important assumptions and implications.[25] We are bound to have made errors in several places. At the same time, we believe that it is possible to assemble a sufficiently complete story to test the plausibility of the proposed policy architectures.

Part I.A discusses our rationale for testing the plausibility of the assumptions underlying conventional policy architectures. Part I.B examines the features of the leading architectures, and Part I.C identifies assumptions that undermine the plausibility of the proposed architectures.

A. *An Intuitive Plausibility Test*

We examine the plausibility that the proposed policy architectures will substantially reduce the risk of catastrophic climate change. In using a plausibility test rather than a quantitative model, we recognize that some degree of rigor will be lost, and precise assessments will not be possible. Nevertheless, we believe that a test for intuitive plausibility can expose weaknesses in the accuracy of assumptions and outcomes that may not be apparent from other methodologies.[26]

The value of plausibility testing is an important aspect of an exchange taking place among William Nordhaus, Martin Weitzman, and other econo-

[25] For example, reports vary regarding the GHG type used for the policy target (e.g., CO_2 or CO_2eq), the emissions source categories included (e.g., industry-only or all sources), the timing and amount of emissions reductions that will achieve particular atmospheric targets, the benchmark year for calculating emissions reductions, the atmospheric targets that will achieve desired temperature targets, whether peak values or values at stabilization should be used, the probabilities and magnitudes of climate harms and costs that may arise from those harms, the impact of various allocations of burdens and benefits on the incentives of developed and developing countries, and the impacts of those allocations on climate and justice goals. *See, e.g.*, Bosetti et al., *supra* note 4, at 5 tbl.1 (noting that some policy architectures identify GHG targets and others do not); *see also* Joseph E. Aldy et al., *Thirteen Plus One: A Comparison of Global Climate Policy Architectures*, 3 CLIMATE POL'Y 373 (2003) (reviewing a number of climate change policy architectures).

[26] *See* Martin L. Weitzman, *Reactions to the Nordhaus Critique* (Feb. 9, 2009) (unpublished manuscript, on file with the Harvard Environmental Law Review). Weitzman suggests that testing intuitive plausibility is not necessarily an "airtight or rigorous" approach, but on an intuitive basis "it should be sufficiently convincing to make a plausible presumptive case that there may be a serious mistreatment of uncertainty in the 'standard' [cost-benefit analysis] of climate change." *Id.* at 2.

mists. Nordhaus's work with cost-benefit models has helped to establish the dominant view that gradual emissions reductions are the preferable response to global GHG emissions.[27] In recent years, Weitzman and others have argued that the dominant economic analysis of climate change fails to account adequately for the low probability, high consequence events associated with extreme climate change and that standard economic analyses are relatively insensitive to these risks.[28] The debate is vigorous and is already beginning to affect the thinking of legal scholars and policymakers.[29]

Underlying much of the exchange is Weitzman's willingness to subject climate change cost-benefit models to a critique based on the intuitive plausibility of the model's assumptions and outputs. According to Weitzman, if the model fails the test, deep structural uncertainties may undermine its conclusions. These uncertainties should be addressed, even if doing so yields policy advice that is accurate but characterized more by "fuzziness" than precision.[30] Weitzman notes that economists have a significant influence on policymaking in large part because their models generate precise answers to difficult policy questions.[31] If the models are not only precise but also accurate, they enable policymakers to devote appropriate levels of resources to the climate problem; but there is a difference between precision and accu-

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[27] *See* WILLIAM D. NORDHAUS & JOSEPH BOYER, WARMING THE WORLD: ECONOMIC MODELS OF GLOBAL WARMING (2000); William D. Nordhaus, *The Challenge of Global Warming: Economic Models and Environmental Policy* 166 (July 24, 2007) (unpublished manuscript, *available at* http://nordhaus.econ.yale.edu/dice_mss_072407_all.pdf); Robert Mendelsohn, *Chapter 8: Robert Mendelsohn, Yale University*, *in* YALE SYMPOSIUM ON THE STERN REVIEW 93, 95 (2007), *available at* www.ycsg.yale.edu/climate/stern.html. The Nordhaus approach has been enormously influential in the academic and policy realms. *See, e.g.*, Cass R. Sunstein, *From Montreal to Kyoto: A Tale of Two Protocols*, 31 HARV. ENVTL. L. REV. 1 (2007) (comparing costs and benefits of efforts to reduce GHGs and ozone-depleting chemicals).

[28] *See, e.g.*, Weitzman, *supra* note 9; *see also* Stern, *supra* note 7, at 3. The implication for policymakers is that reductions should be larger and occur earlier than suggested by the Nordhaus approach. *See, e.g.*, Martin L. Weitzman, *Some Basic Economics of Extreme Climate Change* 3–4 (Working Paper, Feb. 19, 2009), *available at* http://www.economics.harvard.edu/faculty/weitzman/files/Cournot%2528Weitzman%2529.pdf.

[29] *Compare* William D. Nordhaus, *An Analysis of the Dismal Theorem* (Cowles Found. for Research in Econ., Discussion Paper No. 1686, 2009), *available at* http://cowles.econ.yale.edu/P/cd/d16b/d1686.pdf, *with* Weitzman, *supra* note 26. The effect of the debate on policymakers is reflected in a recent article by Peter Orszag, who is now White House Office of Management and Budget ("OMB") Director. Peter R. Orszag & Terry M. Dinan, Response, *Comment on* Of Montreal and Kyoto: A Tale of Two Protocols, 38 Envtl. L. Rep. (Envtl. Law Inst.) 10,579–81 (2008); *see also* Melinda Kimble & Letha Tawney, *The Tale of the Fat Tail*, ENVTL. F., forthcoming May/June 2009.

[30] Weitzman, *supra* note 9, at 2.

[31] Weitzman, *supra* note 26, at 14-15 (noting that "economists make a living from plugging rough numbers into simple models and reaching specific conclusions (more or less) on the basis of these numbers. . . . The public has little tolerance for ambiguity and craves some kind of an answer . . . ."). Economic climate models are sophisticated and opaque to the non-expert, yet yield enormously influential, precise values or ranges of values for the optimal expenditures to reduce GHG emissions. *See, e.g.*, NORDHAUS & BOYER, *supra* note 27, at 69–74.

racy. An inexpensive digital watch may tell time to the tenth of a second, yet be off by an hour.[32]

Our effort here is in a similar vein. The recent economic meltdown suggests that sophisticated models built on prior experience sometimes yield precise but inaccurate answers when they fail to account for low probability, high consequence events.[33] A simple plausibility analysis several years ago might not have yielded precise results, but it might have induced policymakers to take a second look at the financial system while many policy responses were still available.[34] We identify substantial concerns about the plausibility of many conventional climate change policy architectures.

B. *The Happy Story: Proposed Climate Change Policy Architectures*

The principal challenge confronting climate change policymakers is to allocate the benefits and burdens in ways that will induce a sufficient number of the major emitters to participate and yet achieve the desired atmospheric GHG targets. At first glance, the prospects for such an agreement look good. For example, the 2007 Fourth Assessment Report ("AR4") by the Intergovernmental Panel on Climate Change ("IPCC") provides an analysis that suggests that the emissions reduction costs are not daunting.[35] Of the five categories of emissions scenarios analyzed in the AR4, Categories III and IV have been the focus of much attention by policymakers and academicians.[36] The Category III scenarios, which stabilize atmospheric concentrations at roughly 550 ppm CO_2eq,[37] would result in a temperature increase of 2.8°C to 3.2°C above pre-industrial levels.[38] Achieving these

[32] *See, e.g.*, John H. Lienhard, *Engines of Our Ingenuity No. 1742: Accuracy as Precision*, http://www.uh.edu/engines/epi1742.htm (last visited Apr. 16, 2009) (on file with the Harvard Environmental Law Review) (discussing difference between precision and accuracy, using the example of digital and analog watches).

[33] *See, e.g.*, David Segal, *In Letter, Warren Buffett Concedes a Tough Year*, N.Y. TIMES, Mar. 1, 2009, at A16 (quoting Warren Buffett for the proposition that "'[t]he stupefying losses in mortgage-related securities came in large part because of flawed, history-based models'" and noting that Buffett recently criticized "the perils of relying on mathematical models devised without worst-case situations in mind").

[34] *See, e.g.*, Michael Lewis, *The End*, PORTFOLIO, Dec. 2008, at 114 (describing how Steve Eisman profited by betting against how rating agencies were assessing subprime loans and noting that he "called Standard & Poor's and asked what would happen to default rates if real estate prices fell. The man at S&P couldn't say; its model for home prices had no ability to accept a negative number").

[35] *See* IPCC AR4 WG III, *supra* note 7, at 205–06 (noting percentage impact on GDP ranging from single-digit losses to slight gains). The language used by the Framework Convention on Climate Change is to avoid "dangerous anthropogenic interference" ("DAI") with the climate, and the avoidance DAI goal is a focus of the IPCC economic analysis. *Id.* at 194.

[36] *See, e.g.*, Bosetti et al., *supra* note 4, at 6 (identifying 550 CO_2eq ppm target); Simon Dietz et al., *Right for the Right Reasons: A Final Rejoinder on the Stern Review*, 8 WORLD ECON. 229 (2007) (discussing policy allowing for scenarios of 650 to 750+ ppm CO_2eq).

[37] IPCC AR4 WG III, *supra* note 7, at 198 tbl.3.5, 229 tbl.3.10. We use 550 ppm CO_2eq as a rough approximation of the AR4 CO_2eq range of 535 to 590. The AR4 also provides a CO_2 figure of 450 ppm CO_2, or a range from 440 to 485 ppm. *Id.*

[38] *Id.* at 229 tbl.3.10. AR4 Category III atmospheric concentrations are similar to the stabilization at 500 to 550 ppm CO_2eq examined by the Stern Review. *See id.* at 206. Stern

concentrations requires emissions reductions that cause total global emissions to peak within twenty-five years, and by 2050 to be between 30% less and 5% more than year 2000 levels.[39] Costs are expected to be in the range of 0.2 to 2.5% of GDP by 2030, with a 2050 GDP loss that ranges from slightly negative to 4%; by 2100, the GDP losses range from slightly negative to 6.5%.[40]

Similarly, AR4 Category IV stabilizes atmospheric CO_2 concentrations at roughly 650 ppm CO_2eq and would result in a temperature increase of 3.2°C to 4.0°C.[41] Category IV concentrations could be achieved if total global emissions growth by 2050 is limited to an increase of 10 to 60% from 2000 levels.[42] Costs are expected to be in the range of -0.6% to 1.2% of GDP by 2030, with a 2050 GDP loss that ranges from -1% to 2%; by 2100, the GDP losses range from -1.6% to 5%.[43]

These IPCC projections are essentially a consensus view, and they are somewhat comforting. Low single-digit global GDP losses, while not insignificant, do not suggest insuperable problems. With these types of target concentrations and costs as a backdrop, scholars have proposed a number of policy architectures designed to induce participation in a global climate change agreement by developed and developing countries. Scholars have suggested that under a number of different emissions reduction allocations there is some prospect that the major developed and developing nations will view joining in and complying with an international climate agreement to be in their interest.[44] For example, Bosetti et al. recently used a climate-energy-economy model to examine the economic and climate impacts of eight proposed climate policy architectures, including a cap-and-trade scheme with redistribution, a cap-and-trade scheme with the addition of a program for reducing emissions from deforestation and degradation ("REDD"), a global carbon tax, formation of clubs of countries, a research and development scheme, and others.[45] Most of these approaches appear to reach stabilization at just under 3°C, suggesting that they would achieve CO_2eq levels roughly

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estimates that cuts of 30 to 50% by 2050 are necessary to achieve stabilization at 550 ppm CO_2eq, and suggests that these levels could be achieved with a cost of 1% of world GDP or about $30 per ton of CO_2 by 2030. Stern, *supra* note 7, at 3. Stabilization at 550 ppm CO_2eq would require global emissions to peak in the next twenty years. *Id.* at 7.

[39] IPCC AR4 WG III, *supra* note 7, at 198 tbl.3.5, 227, 229 tbl.3.10.

[40] *Id.* at 205–06. The *Stern Review* GDP loss estimate for roughly the same atmospheric concentration is between -2% and +5%. *Id.* at 206.

[41] *Id.* at 198 tbl.3.5, 229 tbl.3.10. Note that as stated by the IPCC, the figure we identify as roughly 650 ppm CO_2eq (stated as a range of 590 to 710 ppm CO_2eq) corresponds roughly with our 550 ppm CO_2 figure (stated as a range from 485 to 570 ppm CO_2). Stern has expressed disagreement with economists who have argued for stabilization levels at or above 650 ppm CO_2eq. *See* Stern, *supra* note 7, at 6 (citing Nordhaus, *supra* note 27, at 166, and Mendelsohn, *supra* note 27, at 95).

[42] IPCC AR4 WG III, *supra* note 7, at 198 tbl.3.5, 229 tbl.3.10. This would require total cumulative emissions not to exceed 2270 to 3920 GtCO2. *Id.* at 198.

[43] *Id.* at 205–06.

[44] *See* Bosetti et al., *supra* note 4, at 4-5 (reviewing recent models).

[45] *Id.*

comparable to AR4 Category III, or roughly 550 ppm CO_2eq. None would generate costs that exceed 1.5% of GWP.[46]

A number of proposals have focused on providing the incentives necessary to induce the major developing countries to participate in an international agreement. For example, India and Germany have proposed convergence between developed and developing country per capita emissions levels, followed by joint reductions.[47] This approach would enable the developed and developing countries to meet in the middle of the current per capita emissions ranges to allow emissions growth and economic growth by developing countries. After the developing countries have gained the economic benefits associated with emissions growth and the developed countries have demonstrated good faith and incurred the costs of reducing emissions toward the convergence point, both the developed and developing countries would reduce emissions to comparable levels.[48] Other proposals use limited or delayed GHG reduction targets to create incentives for developing countries to participate.[49]

In addition, a number of proposed policy architectures explicitly address poverty alleviation.[50] For example, the Greenhouse Development Rights ("GDR") concept developed by EcoEquity and the Stockholm Environment Institute would allocate emissions reductions based on national responsibility for and capacity to reduce emissions, and it would exclude emissions associated with individuals whose annual income and consumption are below $7500 from any country's capacity and responsibility for emissions reductions.[51] A benefit of the GDR approach is that it acknowledges that there are poor and wealthy individuals in developing and developed countries, and it enables a nation-state level allocation to be made that accounts for these populations.[52] Other proposals exclude emissions from individuals at other levels, such as $9000 per capita income.[53] The effect of

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[46] *Id.* at 10, 13.

[47] *See* Robert Engelman, *Sealing the Deal to Save the Climate, in* STATE OF THE WORLD 2009: INTO A WARMING WORLD 169, 184 (Linda Starke ed., 2009); Stern, *supra* note 7, at 28–31. In 1997, Brazil proposed allocation based on stocks, or historical contributions. *See* Proposed Elements of a Protocol to the United Nations Framework Convention on Climate Change, Presented by Brazil in Response to the Berlin Mandate, (submitted May 28, 1997), *available at* http://unfccc.int/cop4/resource/docs/1997/agbm/misc01a3.htm.

[48] *See* Jing Cao, *supra* note 5, at 10, 11.

[49] *See* Frankel, *supra* note 5, at 16 fig.2. By participate, we mean both to enter into and comply with an agreement to reduce GHG emissions.

[50] *See, e.g.*, Jing Cao, *supra* note 5, at 11 (citing PAUL BAER ET AL., THE RIGHT TO DEVELOPMENT IN A CLIMATE CONSTRAINED WORLD: THE GREENHOUSE DEVELOPMENT RIGHTS FRAMEWORK (2007)); *see also* Aldy & Stavins, *supra* note 2, at 9, 19.

[51] *See* Engelman, *supra* note 47, at 185–86. ECOEQUITY & STOCKHOLM ENV'T INST., EXECUTIVE SUMMARY, THE RIGHT TO DEVELOPMENT IN A CLIMATE CONSTRAINED WORLD: THE GREENHOUSE DEVELOPMENT RIGHTS FRAMEWORK 2–3 (2d ed. 2008), *available at* www.ecoequity.org/GDRs/GDRs_ExecSummary.html.

[52] *See, e.g.*, Posner & Sunstein, *supra* note 1, at 1582 (noting that "[n]ations are not people; they are collections of people, ranging from very rich to very poor").

[53] *See* Jing Cao, *supra* note 5, at 11.

these approaches is to generate emissions allocations that allow for and induce per capita income growth among the poor.

In sum, the implications of the IPCC AR4 and a wide range of proposed policy architectures are that an international climate agreement can be secured that will achieve climate goals, will be affordable using conventional approaches, and will result in poverty alleviation. This is the happy story.

C. *The Other Story: The Plausibility of Proposed Policy Architectures*

The other story is more troubling. A number of extremely optimistic assumptions undermine the plausibility of the proposed policy architectures. Our analysis raises serious doubts about whether any conventional policy architecture will achieve a viable agreement that substantially reduces the risk of catastrophic climate change.[54]

1. *Atmospheric and Temperature Targets*

The first concern is that the dominant policy architectures seek to achieve atmospheric concentrations and temperatures that do not meet the widely adopted 2°C temperature target, and the higher temperature targets of the proposed architectures will leave surprisingly high likelihoods of catastrophic climate harms. Policymakers first converged on 2°C almost two decades ago as the upper bound of the temperature increase as compared to pre-industrial levels that can occur without an unacceptable increase in the risk of catastrophic climate change.[55] Presumably to achieve a target temperature increase of roughly 2°C, public international organizations in the

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[54] Some modeling results demonstrate the difficulty of relying only on conventional approaches. For example, one model suggests that even with a target of 550 CO_2eq, the largest emitting nations must substantially reduce emissions by 2050, including 80% reductions by the United States and slower emission growth rates by China. Even in this scenario, the planet is likely to be 4 to 6°C warmer. *See* Richard Harris, *Innovation Seen as Key to Curbing Climate Change*, NPR, Feb. 4, 2009, http://www.npr.org/templates/story/story.php?storyId=100229450 (on file with the Harvard Environmental Law Review). To achieve a lower atmospheric concentration such as 400 ppm CO_2eq, one scenario would require that the eight largest industrialized nations and the biggest rapidly industrializing nations, including China and India, each reduce emissions by 5% per year, and would require stable emissions from the rest of the world. The costs would be in the tens of trillions of dollars. *Id.*

[55] In 1990, the WMO/ICSU/UNEP Advisory Group on Greenhouse Gases ("AGGG") concluded that 2°C was "an upper limit beyond which the risks of grave damage to ecosystems, and of non-linear responses, are expected to increase rapidly." AGGG, STOCKHOLM ENVTL. INST., REPORT OF WORKING GROUP II OF THE AGGG, TARGETS AND INDICATORS OF CLIMATE CHANGE (1990); *see also* IPCC AR4 WG III, *supra* note 7, at 99. The European Union adopted the 2°C target on November 15, 2007, in a European Parliament Resolution. Resolution on Limiting Global Climate Change to 2°Celsius — The Way Ahead for the Bali Conference on Climate Change and Beyond, EUR. PARL. DOC. (COP 13 and COP/MOP3) 1-2 (2007), *available at* http://www.europarl.europa.eu/oeil/DownloadSP.do?id=14318&num_rep=7021&language=en.

developed world,[56] national governments, provinces and states[57] and other sub-national governments,[58] private corporations,[59] and non-governmental organizations[60] have coalesced around an emissions reduction goal for the developed world of roughly 80% by 2050.

Despite the widespread adoption of the 2°C goal, it is difficult to identify a proposed policy architecture that seeks to achieve 2°C or less.[61] For example, the eight policy architectures evaluated by Bosetti et al. generate temperature increases in the 2.5 to 3°C range, which is roughly consistent

[56] For example, after adopting the 2°C target in 2007, the European Parliament adopted the "Florenz report," which calls for the European Union to reduce GHG emissions to 80% below 1990 levels by 2050. *See* 2050: The Future Begins Today — Recommendations for the EU's Future Integrated Policy on Climate Change, EUR. PARL. DOC. 2008/2105 (INI) (2009), *available at* http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+TA+P6-TA-2009-0042+0DOC+XML+V0//EN&language=EN. AR4 Category I atmospheric concentrations, which would achieve a 2.0 to 2.4°C temperature target, would require 80% to 95% emissions reductions from developed countries by 2050. *See* IPCC AR4 WG III, *supra* note 7, at 776 box 13.7.

[57] For example, California has set emissions reductions targets for all GHGs to 2000 levels by 2012, 1990 levels by 2020, and 80% below 1990 levels by 2050. Cal. Exec. Order No. S-3-05 (2005), *available at* http://www.dot.ca.gov/hq/energy/ExecOrderS-3-05.htm. Florida has set emissions reduction targets for all GHGs to 2000 levels by 2017, 1990 levels by 2025, and 80% below 1990 levels by 2050. Fla. Exec. Order No. 07-127, at 2 (2007), *available at* http://www.flgov.com/pdfs/orders/07-127-emissions.pdf. The New Jersey Global Warming Response Act limits the level of statewide GHG emissions to 1990 levels by 2020, and 80% below 2006 levels by 2050. Assem. 3301, 212th Leg., § 2 (N.J. 2007), *available at* http://www.njleg.state.nj.us/2006/Bills/A3500/3301_R2.PDF.

[58] The members of the U.S. Conference of Mayors adopted a resolution calling for reduction of all GHG emissions 80% below 1990 levels by 2050. 76TH U.S. CONFERENCE OF MAYORS, CITY PRIORITIES FOR A CAP AND TRADE SYSTEM (2008), *available at* http://www.usmayors.org/resolutions/76th_conference/energy_11.asp.

[59] As of January 2009, the members of the United States Climate Action Partnership ("USCAP"), including more than two dozen large corporations, have supported a GHG emissions goal of 97 to 102% of 2005 levels by 2012, 80 to 86% of 2005 levels by 2020, 58% of 2005 levels by 2030, and 20% of 2005 levels by 2050. *See* U.S. CLIMATE ACTION P'SHIP, A BLUEPRINT FOR LEGISLATIVE ACTION 5 (2009), *available at* http://www.us-cap.org/pdf/USCAP_Blueprint.pdf.

[60] The signatories to the American College and University Presidents Climate Commitment have called for an 80% reduction in emissions of all GHGs by 2050, although the commitment does not specify a baseline. Am. Coll. & Univ. Presidents Climate Commitment, American College & University Presidents Climate Commitment 1 (2008), *available at* http://www.presidentsclimatecommitment.org/html/commitment.pdf. Hundreds of college and university presidents have signed the commitment. American College & University Presidents Climate Commitment, Signatories of the ACUPCC, http://www.presidentsclimatecommitment.org/html/signatories.php (last visited Apr. 26, 2009) (on file with the Harvard Environmental Law Review).

[61] One NGO advocates a 350 ppm CO_2 standard, which would translate to roughly 400 to 450 ppm CO_2eq, but the group has not proposed a policy architecture for achieving this target. *See* Understanding 350, http://www.350.org/understanding-350 (last visited Apr. 17, 2009) (on file with the Harvard Environmental Law Review) (identifying a strategy of political activism to encourage international consensus that would "put a high enough price on carbon that we stop using so much" and to effectively reduce "carbon 80% by 2050," and mentioning that this would entail a switch to non-coal energy, better land-use, and waste reduction); *see also* IPCC AR4 WG III, *supra* note 7, at 229 tbl.3.10 (noting that 350 ppm CO_2 is consistent with 445 ppm CO_2eq).

with the temperature increases associated with AR4 Category III.[62] If emissions are reduced to the Category III level, stabilization will occur at atmospheric concentrations of roughly 550 ppm CO_2eq and with a temperature increase of 2.8 to 3.2°C.[63] If emissions are reduced to the AR4 Category IV level, stabilization will occur at atmospheric concentrations of roughly 650 ppm CO_2eq and a temperature increase of 3.2 to 4°C over pre-industrial levels.[64] None of the architectures evaluated by Bosetti et al. will limit likely temperature increases to 2°C or less, and all would allow increases approaching 3°C or more.[65]

The bad news is that even if we assume that these temperature targets will enable emissions allocations that achieve a viable international agreement (a point we return to in the next Section), the targets will leave a substantial possibility of catastrophic climate change.[66] Only AR4 Category I, the most aggressive of the four AR4 categories, has the prospect of achieving the 2°C target, and even then it will do so only if the actual temperature increases are at the lowest end of the projected temperature range[67]: AR4 Category I stabilizes atmospheric concentrations at roughly 450 ppm CO_2eq,[68] which would result in a temperature increase of roughly 2.0 to 2.4°C.[69]

a. Climate Economics: Tail Risks

Now the truly bad news. Recent developments suggest that the risk of catastrophic climate change is even greater than when policymakers set the targets at 2°C and when the risks were identified in the AR4.[70] As discussed above, economists and climate scientists have become increasingly focused on the risks that remain even at atmospheric concentrations of 450 to 550 ppm CO_2eq. Perhaps the most accessible presentation of these thick tail

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[62] Bosetti et al., *supra* note 4, at 11. Current atmospheric concentrations are roughly 430 ppm CO_2eq and are increasing by over 2 ppm per year. *See* Stern, *supra* note 7, at 4; *see also* W.L. Hare, *A Safe Landing for the Climate, in* STATE OF THE WORLD 2009: INTO A WARMING WORLD, *supra* note 47, at 13.

[63] IPCC AR4 WG III, *supra* note 7, at 229 tbl.3.10.

[64] *Id.*

[65] Bosetti et al., *supra* note 4, at 11 fig.3, 11–12, 15. The lowest likely temperature increase in the eight policy architectures examined by Bosetti et al. is over 2.5°C. *Id.* at 11 fig.3.

[66] The 2007 IPCC AR4 suggests that an atmospheric concentration range of 500 to 550 ppm CO_2eq, at the low end of the Category III levels, will leave an 80% risk that warming will exceed 3°C. The risk will be much higher at Category IV levels. *See* IPCC AR4 WG III, *supra* note 7, at 227 tbl.3.9; Hare, *supra* note 62, at 13–22, 23 (noting that stabilizing at 475 ppm CO_2eq still generates a 50% risk that warming will exceed 2°C).

[67] Hare, *supra* note 62, at 25 (noting that achieving 2°C peak temperature would require 400 ppm CO_2eq levels).

[68] The IPCC AR4 refers to concentrations of between 350 and 400 ppm CO_2, and CO_2eq at 445 to 490 ppm. IPCC AR4 WG III, *supra* note 7, at 198 tbl.3.5, 229 tbl.3.10.

[69] *Id.*; *see also* Hare, *supra* note 62, at 28 (noting that it is unlikely that this scenario will stabilize temperatures at 2°C or less).

[70] Hare, *supra* note 62, at 19 (noting that "[a] warming of 2 degrees Celsius is clearly not 'safe' and would not prevent, with high certainty, dangerous interference with the climate system").

risks appears in Table 1, which was published by economist Sir Nicholas Stern in 2008.

TABLE 1. PERCENT LIKELIHOOD OF EXCEEDING A TEMPERATURE INCREASE AT EQUILIBRIUM[71]

Stabilization Level (ppm of CO_2eq)	2°	3°	4°	5°	6°	7°
450 ppm	78	18	3	1	0	0
500 ppm	96	44	11	3	1	0
550 ppm (doubling)	99	69	24	7	2	1
650 ppm	100	94	58	24	9	4
750 ppm	100	99	82	47	22	9

If the analysis presented in Table 1 is correct, even at 450 ppm CO_2eq (roughly the AR4 Category I level, which is substantially lower than the targets of many proposed policy architectures) there is a substantial likelihood of temperature increases in the 3 to 5°C range. At CO_2eq atmospheric concentrations of 550 ppm (roughly the AR4 Category III level, and a common target for proposed policy architectures) there is a substantial likelihood of temperature increases of 5°C or more.[72] At temperatures in this range, the ice and snow cover around the world may disappear, and sea level rises of ten meters or more could occur.[73]

In addition, economist Martin Weitzman reads the six emissions scenarios in the IPCC AR4 to imply a mean temperature increase of 2.8°C, with about a 2% chance of a greater than 6°C temperature increase.[74] He asserts that 2% is a far higher probability than the risks tolerated in many other areas and that at 6°C or higher, conditions will be "in the *terra incognita* of what any honest economic modeler would have to admit is a planet Earth reconfigured as science fiction."[75] Although Weitzman and others are debating the appropriate treatment of thick tail risks, and it is too soon to know how the debate will be resolved, the debate should at a minimum give us pause about whether the atmospheric target assumptions embedded in the

[71] Stern, *supra* note 7, at 5 tbl.1 (citing work of the Hadley Center as published in the Stern Review).

[72] *Id.*

[73] *Id.* at 6. The Garnaut Climate Change Review concluded that temperature increases above 5.1°C would "result in a severe" reduction in human welfare. "Their impacts on human civilisation and most ecosystems are likely to be catastrophic." GARNAUT, *supra* note 7, at 263.

[74] Martin L. Weitzman, *A Review of* The Stern Review on the Economics of Climate Change, 45 J. ECON. LITERATURE 703, 716 (2008).

[75] *Id.*

leading proposed policy architectures will leave unacceptably high risks of catastrophic climate change.

b. *Climate Science: Post-AR4 Developments*

In addition, recent climate science suggests that earlier analyses underestimated both the extent and impact of future atmospheric GHG stocks.[76] First, new research suggests that a substantial amount of temperature increase, changes in weather patterns, and sea level rise will occur and will be "largely irreversible" even based on existing atmospheric GHG levels.[77] Second, carbon emissions are growing at a faster rate than projected by the IPCC, although the growth will be reduced in the near-term by the economic crisis.[78] Third, Arctic sea ice is melting faster than projected by the IPCC.[79] Sea ice reflects most of the sun's energy, but open ocean serves as a giant sponge, absorbing most of that energy and contributing to additional ice-melting and warming, and additional releases of carbon dioxide and methane.[80] Recent scientific studies suggest that even at 2°C the Arctic summer ice, and eventually the Greenland ice sheet, may be lost, and that the widely-reported AR4 projection of a 0.18 to 0.59 meter sea level rise by 2100 is too conservative.[81] Finally, Antarctica is warming and has been losing glacial mass at an increasing rate.[82] The recent scientific developments have in-

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[76] *See, e.g.*, Cameron Hepburn & Nicholas Stern, *A New Global Deal on Climate Change*, 24 OXFORD REV. ECON. POL'Y 259, 265 (2008); *see also* D.A. Stainforth et al., Letter, *Uncertainty in Predictions of the Climate Response to Rising Levels of Greenhouse Gases*, 433 NATURE 403 (2005); Malte Meinshausen, *What Does a 2°C Target Mean for Greenhouse Gas Concentrations? A Brief Analysis Based on Multi-Gas Emission Pathways and Several Climate Sensitivity Uncertainty Estimates*, *in* AVOIDING DANGEROUS CLIMATE CHANGE 265 (Hans Joachim Schellnhuber et al. eds., 2006).

[77] Susan Solomon et al., *Irreversible Climate Change Due to Carbon Dioxide Emissions*, 106 PROC. NAT'L ACAD. SCI. 1704, 1704 (2009). For an overview of recent scientific developments, see Michael D. Lemonick, *As Effects of Warming Grow, U.N. Report Is Quickly Dated*, YALE ENV'T 360, Feb. 12, 2009, http://www.e360.yale.edu/content/print.msp?id=2120 (on file with the Harvard Environmental Law Review).

[78] Emissions over the last several years have increased at rates depicted by the very aggressive IPCC A1F1 scenario. *See* Hepburn & Stern, *supra* note 76, at 265. Additionally, atmospheric concentrations of GHGs are increasing faster than many models predict. *See* Peter Tans, Earth System Research Laboratory, Trends in Atmospheric Carbon Dioxide — Global (2008), *available at* http://www.esrl.noaa.gov/gmd/ccgg/trends/index.html#global.

[79] *See* Julienne Stroeve et al., *Arctic Sea Ice Extent Plummets in 2007*, 89 Eos 13 (2008).

[80] *See* Lemonick, *supra* note 77, at 2.

[81] *See* Timothy M. Lenton et al., *Tipping Elements in the Earth's Climate System*, 105 PROC. NAT'L ACAD. SCI. 1786, 1789 (2008) (discussing loss of ice); Andrew Shepherd & Duncan Wingham, *Recent Sea-Level Contributions of the Antarctic and Greenland Ice Sheets*, 315 SCIENCE 1529 (2007) (regarding Greenland and Antarctic ice); Tad Pfeffer et al., *Kinematic Constraints on Glacier Contributions to 21st-Century Sea Level Rise*, 321 SCIENCE 1340 (2008) (regarding sea level rise within 100 years); David M. Lawrence et al., *Accelerated Arctic Land Warming and Permafrost Degradation During Rapid Sea Ice Loss*, GEOPHYSICAL RES. LETTERS (March 7, 2008) (unpublished manuscript on file with the Harvard Environmental Law Review) (referring to 100 year time span).

[82] *See* Eric Rignot et al., Letter, *Recent Antarctic Ice Mass Loss from Radar Interferometry and Regional Climate Modelling*, 1 NATURE GEOSCIENCE 106, 106–07 (2008); *see also* Eric J. Steig et al., Letter, *Warming of the Antarctic Ice-Sheet Surface Since the 1957 International*

duced a number of scholars to call for atmospheric targets of 450 ppm CO_2eq or below and temperature targets of 2°C or below.[83] As with the thick tail debate, these developments raise questions about the atmospheric target assumptions embedded in the proposed policy architectures.

2. *Technological and Market Assumptions*

Even if we assume that 550 ppm CO_2eq (or roughly a 3°C temperature increase) is an adequate goal, the costs and viability of achieving this goal with conventional measures are daunting. For example, even if AR4 Category III or IV levels of emissions reductions are acceptable, the cost estimates of achieving those reductions rely on very favorable assumptions. The models tend to assume no transaction costs, transparent markets, and perfect implementation of policy measures until 2100.[84] According to the AR4, "[r]elaxation of these modeling assumptions . . . will lead to an appreciable increase in all cost categories."[85]

The models evaluated by the IPCC not only assume no transaction or adoption costs and perfect markets, but also rapid development and deployment of new technologies, including carbon capture and storage ("CCS").[86] According to Stern, given the difficulty of reducing agricultural emissions, and the likelihood that richer nations will need to make greater cuts than poorer ones, the richer nations may need to achieve near-zero carbon emissions from the transportation and power sectors, which would require "radical" technological changes and "an end to deforestation."[87] Some scenarios for achieving 60 to 80% CO_2 emissions reductions by 2050 assume improvements in energy intensity and carbon intensity of roughly three times current levels.[88] The IPCC concludes that "technology and technological change

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Geophysical Year, 457 NATURE 459, 460 (2009) (reporting that new Antarctic temperature model, using more data sources and improved statistical methods, demonstrates "more significant temperature change in Antarctica . . . than reported in some previous [temperature] reconstructions").

[83] Drawing in part on scientific studies available after the IPCC AR4, the 2008 Garnaut Report, which was commissioned by the Australian government, suggests that Australia pursue an atmospheric target of 450 ppm CO_2eq. *See* GARNAUT, *supra* note 7, at 268–72 (concluding that 450 ppm CO_2eq is justified by several cost-benefit analyses). Stern has advocated 500 ppm CO_2eq. Hepburn & Stern, *supra* note 76, at 277. Hansen has argued that, based on the current science, 2°C is too high if the goal is to reduce the risk of substantial long-term sea level increases, and that we have already exceeded the desired atmospheric GHG concentrations. *See* James Hansen et al., *Target Atmospheric CO_2: Where Should Humanity Aim?*, 2 OPEN ATMOSPHERIC SCI. J. 217, 217–18, 226 (2008); *see also* James Hansen et al., *Dangerous Human-Made Interference with Climate: A GISS ModelE Study*, 7 ATMOSPHERIC CHEMISTRY & PHYSICS 2287, 2304–08 (2007).

[84] IPCC AR4 WG III, *supra* note 7, at 204.

[85] *Id.*

[86] *Id.* at 202–03.

[87] Stern, *supra* note 7, at 7–8.

[88] IPCC AR4 WG III, *supra* note 7, at 216 (citing REINA KAWASE ET AL., NAT'L INST. FOR ENVTL. STUDIES, JAPAN, CGER-D038-2006, GREENHOUSE GAS EMISSION SCENARIOS DATABASE AND REGIONAL MITIGATION ANALYSIS (2006)). According to the IPCC, "[m]ost

offer the main possibilities for reducing future emissions and achieving the eventual stabilization of atmospheric concentrations of GHGs . . . ."[89]

Assuming a substantial amount of technological development is plausible and is a common strategy. For example, the Pacala and Socolow stabilization wedge strategy suggests that emissions can be leveled off in the near term with vigorous deployment and development of currently available technologies, and they suggest that their wedges will buy time for the development of new technologies that can begin steep reductions by 2050.[90] The new technologies must provide energy to both buildings and transport with near-zero carbon emissions, however, and must do so at prices and with other characteristics that induce prompt and widespread uptake in developed and developing countries. Pacala and Socolow describe the necessary new technologies as "revolutionary."[91]

Stern has suggested that even just to achieve 50% global reductions by 2050, "richer countries will need to have close to zero emissions in power (electricity) and transport . . . ."[92] "[R]adical changes to the source and use of energy, including much greater energy efficiency," would be required to achieve these reductions.[93] Even the Stern Report, which was criticized for being too aggressive in its recommendations for emissions reductions and too optimistic about the costs of mitigation, rejected modeling the costs of achieving concentrations below 450 ppm CO_2eq, not because these reductions were unnecessary to achieve the 2°C target, but because they were viewed to be "excessively difficult and costly."[94]

According to the IPCC, the assumptions necessary to achieve AR4 Category I atmospheric concentrations and temperature levels, which are likely to result in temperature increases close to 2°C, are extreme. Most scenarios that achieve Category I levels begin emissions reductions before 2015[95] and reduce total global emissions by 50 to 85% from 2000 levels by 2050.[96] The IPCC AR4 analysis suggests that to achieve 450 ppm CO_2eq levels, industrialized countries would need to make 25 to 40% cuts in GHGs below 1990 levels by 2020, and 80 to 95% cuts by 2050.[97] Latin America, East Asia (including China), and the Middle East would need to make substantial reductions in emissions growth by 2020. South Asia (including India) and

of the scenarios with drastic CO2 reductions for the USA and the UK assume the introduction of CCS." *Id.* at 217.

[89] *Id.* at 218.

[90] Stephen Pacala & Robert Socolow, *Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies*, 305 SCIENCE 968, 968–69 (2004).

[91] *Id.* at 968 (concluding that "revolutionary technologies" need to be developed to achieve reductions above leveling off emissions growth).

[92] Hepburn & Stern, *supra* note 76, at 264.

[93] *Id.*

[94] *Id.* at 263.

[95] IPCC AR4 WG III, *supra* note 7, at 199.

[96] *Id.* Stern estimates that cuts of 70% are necessary to achieve stabilization at 450ppm CO_2eq. Stern, *supra* note 7, at 7.

[97] Hare, *supra* note 62, at 28.

Africa would not need to make substantial reductions in emissions growth. All regions would have to halt emissions growth by 2050.[98]

In addition, a target of 400 ppm CO_2eq will provide more comfort that the 2°C threshold will not be exceeded, but according to one estimate it will require near-zero worldwide carbon emissions between 2050 and 2100, and *negative* emissions (removal of GHGs from the atmosphere) in the last quarter of the century (e.g., through biomass energy capture and storage).[99] Other recent scenarios that achieve 400 ppm CO_2eq[100] require 60 to 70% CO_2 reductions from 1990 levels by 2050, and 40 to 60% total global GHG cuts by 2050. All have negative CO_2 emissions in the second half of the century.[101]

We do not know what achieving stabilization at or below 2°C would cost. Few cost estimates of Category I emissions reductions have been prepared, and the cost estimates that have been prepared tend to assume low baseline emissions levels that appear unrealistic given the recent global emissions growth.[102] We do know that, according to the IPCC, "[t]he attainability of such low [Category 1] targets is shown to depend on: 1) using a wide range of different reduction options; and 2) the technology 'readiness' of advanced technologies, in particular the combination of bio-energy, carbon capture and geologic storage (BECCS)."[103] The IPCC also states that "[a]chieving these low-emission trajectories requires a comprehensive global mitigation effort, including a further tightening of existing climate policies in Annex I countries, and simultaneous emission mitigation in developing countries, where most of the increase in emissions is expected in the coming decades."[104] Not surprisingly, Bosetti et al. conclude that "more drastic measures" than the current proposed policy architectures would be required to meet the 2°C goal.[105]

Of course, one or more near-miraculous technological developments could achieve atmospheric concentrations at 450 ppm CO_2eq or below and increase the likelihood that temperature increases will not exceed 2°C. But these technologies would need to provide energy for transport and buildings with almost no net carbon emissions. Perhaps it is not surprising that schol-

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[98] *Id.* at 29.

[99] *Id.* at 23–25.

[100] *Id.* at 26. Hare describes 450 ppm CO_2eq as "far higher" than the atmospheric stabilization concentrations necessary to achieve a high likelihood of limiting warming to 2°C or less. *Id.* at 28.

[101] *Id.* at 26.

[102] By making optimistic assumptions about baselines, some cost estimates project GDP losses by 2030 of only 3% or less, with a 2050 GDP loss that is generally less than 5.5%. IPCC AR4 WG III, *supra* note 7, at 205–06. The Stern Review cost estimate for roughly the same atmospheric concentration was for a GDP loss of between -2% and +5%. *Id.* at 206. Too few assessments have been done of Category I costs in 2100 for analysis by the IPCC in AR4. *Id.* at 205–06.

[103] *Id.* at 198.

[104] *Id.* at 199.

[105] Bosetti et al., *supra* note 4, at 20 (concluding that "the 2°C temperature target as envisaged by the IPCC and the European Commission requires more drastic measures than those indicated in all the policy architectures considered in this paper").

ars use terms like "drastic,"[106] "revolutionary,"[107] and "radical"[108] to describe the technological developments necessary to achieve emissions reduction levels that are likely to achieve the 2°C goal. In our view, although the development and deployment of such technologies is not impossible, it is not prudent to develop a policy that will fail if the technological change does not occur as rapidly as assumed.

3. *Incentive Creation Through Emissions Allocations and Deadlines*

To be plausible, any proposed policy architecture must identify allocations of benefits and burdens that will achieve a viable international agreement. One means of inducing developing countries to sign on to an agreement is to provide them with incentives through excess emissions allowances, extended compliance deadlines, or side payments in the form of cash, technology transfers, or other means. Yet given the global emissions reductions that are necessary even to achieve a 3°C temperature target, the ability to provide incentives in the form of excess allowances and extended compliance deadlines is limited.[109] A brief review of per-capita and per-country emissions suggests that the proposed policy architectures include very optimistic assumptions about the incentives of the major emitting countries.

a. *Per Capita Analysis*

A first test of the plausibility of current proposals to address poverty and catastrophic climate change is a per capita analysis. To achieve roughly 550 ppm CO_2eq (which would still result in temperatures that are more likely to result in a temperature increase of roughly 3°C than 2°C), if in 2050 the world's population is 9 billion (as expected), global annual per capita emissions would need to be reduced by 50%, to roughly two tons of CO_2eq per person.[110] The reductions necessary to get to a two ton per capita level are all the more daunting because they must take place against a baseline of doubling under business as usual assumptions.[111]

The two ton per capita level would require massive reductions in developed countries, which now have far higher per capita emissions. For example, the United States is at roughly twenty tons of CO_2eq per capita today, suggesting that a 90% reduction in per capita emissions would be necessary

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[106] *Id.*

[107] Pacala & Socolow, *supra* note 90, at 968.

[108] Hepburn & Stern, *supra* note 76, at 264.

[109] Stern has recognized the difficulty of providing sufficient over-allocation of allowances to developing countries. Stern, *supra* note 7, at 31.

[110] *See, e.g.*, *id.* at 28; *see also* GARNAUT, *supra* note 7, at 202–03; Posner & Sunstein, *Per Capita*, *supra* note 18, at 52–53 (noting the importance of per capita analyses in climate negotiations); Vandenbergh, *supra* note 22, at 916–17 (noting that "the 2050 target will require global per capita emissions to be far below current Chinese levels").

[111] *See, e.g.*, Pacala & Socolow, *supra* note 90, at 969 fig.1 (identifying business-as-usual emissions projections for 2050).

by 2050 if the target is two tons per capita. Japan and Europe are in the ten ton range now, suggesting the need for an 80% reduction.[112] As we note above, emissions reductions of these levels would require near-zero emissions from buildings and transportation unless substantial reductions are achieved from other sectors.[113]

The two ton per capita limit also casts doubt on the political viability of proposed architectures that would enable economic growth via substantial per capita emissions growth in developing countries. To get a sense of the challenge of achieving the two ton level, per capita emissions will need to be one-half to one-third of current Chinese emissions, and about equal to current Indian emissions.[114] China alone has accounted for two-thirds of the growth in world carbon emissions since 2000 and is expected to grow substantially on an aggregate and per capita basis.[115] China is now the largest GHG-emitting nation, and it recently reiterated its position that economic growth is a higher priority than GHG emissions reductions.[116]

The prospects that China, with roughly 36% of its population living on less than two dollars per day (a figure close to the World Bank poverty line),[117] will commit to and comply with an agreement obligating it to reduce GHG emissions by half by 2050 are vanishingly small at this point.[118] Similarly, it is difficult to imagine that India will commit to no growth in per capita GHG emissions by 2050, particularly given that roughly 76% of its population is living on two dollars or less per day.[119] We discuss the poverty issue in more detail below, but even in the absence of poverty issues, the prospects for inducing China, India, and other developing countries to perceive these targets as in their interest are limited.

b. *Major Emitting Countries*

A second approach to evaluating the plausibility of proposed architectures is to simplify the analysis by focusing on the largest emitting countries to understand the extent of the emissions reductions necessary from the major players. Table 2 identifies the fifteen largest emitting countries in 2005 in terms of total GHG emissions. The list of fifteen leading emitters in-

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[112] Stern, *supra* note 7, at 29.

[113] *Id.* at 7–9.

[114] *See id.* at 28.

[115] *Id.* at 4-5.

[116] Dean Scott, *China: Top Priority Remains Economic Growth, Not Curbing Emissions, Ambassador Says*, 40 Env't Rep. (BNA) 326 (2009).

[117] WORLD BANK, POVERTY DATA: A SUPPLEMENT TO WORLD DEVELOPMENT INDICATORS 2008, at 19 tbl.S.2 (2008), *available at* http://siteresources.worldbank.org/DATASTATISTICS/Resources/WDI08supplement1216.pdf.

[118] Posner and Sunstein have noted the importance of addressing the equity arguments of poor countries in efforts to induce them to enter into a post-Kyoto treaty with substantial, binding commitments. *See* Posner & Sunstein, *supra* note 1, at 1608.

[119] WORLD BANK, supra note 117, at 19 tbl.S.2.

cludes five developing countries: China, India, Brazil, Mexico, and Indonesia.[120]

TABLE 2. TOTAL GHG EMISSIONS (2005)[121]

Total CO_2 Rank	Country	$MtCO_2$	% of World Total	Tons of CO_2 Per Person	Per Capita Rank
1	China	7,250	18.7%	5.6	71
2	United States	7,098	18.3%	23.9	8
-	European Union	5,342	13.8%	10.9	-
3	Russian Federation	1,992	5.1%	13.9	19
4	India	1,863	4.8%	1.7	120
5	Japan	1,383	3.6%	10.8	39
6	Brazil	1,028	2.7%	5.5	73
7	Germany	1,006	2.6%	12.2	30
8	Canada	736	1.9%	22.8	9
9	United Kingdom	683	1.8%	11.3	36
10	Mexico	641	1.7%	6.2	64
11	Indonesia	598	1.5%	2.7	100
12	Italy	588	1.5%	10	44
13	Korea (South)	588	1.5%	12.2	31
14	France	576	1.5%	9.5	45
15	Iran	571	1.5%	8.3	54

*Includes CO_2, CH_4, N_2O, PFCs, HFCs, SF_6, and international bunkers; excludes land-use change

[120] We refer to China as a developing country in this Article, although we recognize that China and several other developing countries are rapidly industrializing. *See, e.g.*, Stern, *supra* note 7, at 22 (discussing China as a part of the "developing world"); Posner & Sunstein, *Per Capita*, *supra* note 18, at 54 (noting that China, India, and Brazil are "developing countries that are, or will soon be, industrial powers"). The totals exclude emissions from land use and forestry, for which only data from 2000 are available and the reliability of the data is unclear. The United Nations Framework Convention on Climate Change ("UNFCCC") has cautioned that "[p]arties reported difficulties in obtaining activity data for the time series needed for the LUCF sector, as requested by the IPCC methodology. National data on land use and forest cover were often outdated or not in a suitable format." UNFCCC, Subsidiary Body for Implementation, *Sixth Compilation and Synthesis of Initial Communications from Parties Not Included in Annex I to the Convention*, ¶ 87, U.N. Doc. FCCC/SBI/2005/18 (Oct. 25, 2005), *available at* http://unfccc.int/resource/docs/2005/sbi/eng/18.pdf. Nevertheless, it is clear that Indonesia and Brazil accounted for a large share of global land-use carbon emissions. *See* Richard Houghton, Data Note, *Emissions (and Sinks) of Carbon from Land-Use Change* 1 (Report to the World Resources Institute from the Woods Hole Research Center, 2003), *available at* http://cait.wri.org/downloads/DN-LUCF.pdf. For an analysis for major emitting countries, see Sunstein, *supra* note 3.

[121] WRI-CAIT, *supra* note 16. The WRI-CAIT data include and rank the European Union ("EU") for comparison purposes. Since other EU member countries are ranked as well, we have removed the EU ranking and adjusted the rankings of the other countries to reflect this change.

The five largest emitters among the developing countries (China, India, Brazil, Mexico, and Indonesia) account for almost 30% of the GHG emissions from all countries. These five developing countries also have projected emissions growth rates that are among the steepest of all major emitters. For example, the International Energy Agency ("IEA") predicts that the energy-related emissions in the business as usual case will be 225% larger for China in 2030, 190% for India, 177% for Brazil, 172% for Mexico, and 190% for Indonesia.[122] In fact, 97% of the increase in global energy-related CO_2 emissions is expected to arise from countries that are not among the industrialized countries that comprise the Organization for Economic Cooperation and Development ("OECD").[123] To achieve a global 50% emissions reduction when five of the top fifteen countries have steep growth rates will require extraordinary reductions from business as usual levels.

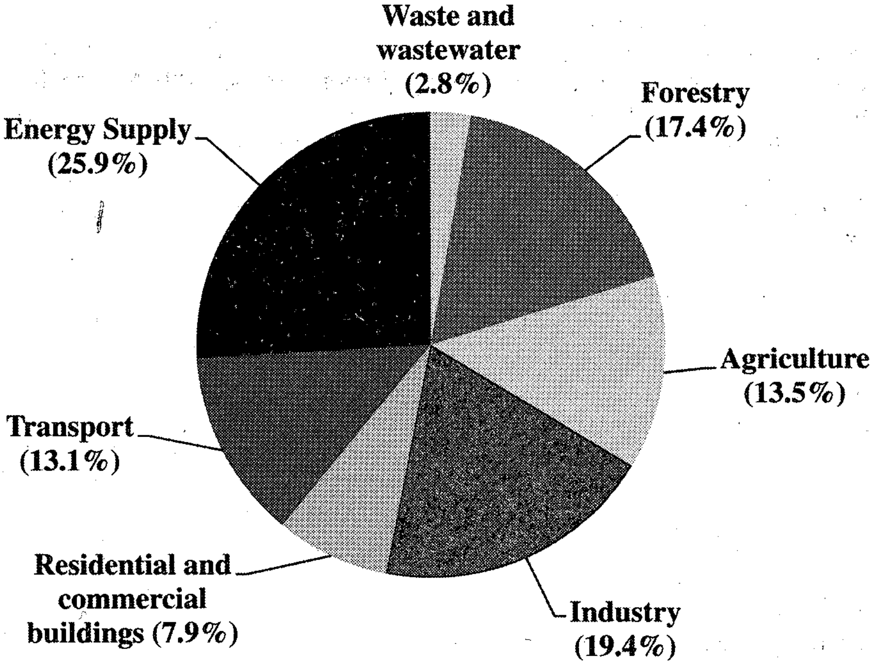
c. Major Emitting Sectors

A third test of intuitive plausibility focuses on the categories of source types, rather than national per capita or aggregate emissions. The problem with the scope of the needed reductions from developing countries is confounded by the fact that the emissions categories above exclude GHG emissions from agriculture, forestry, and other land use changes, which make up a large share of the emissions from these five countries. Data presented in Figure 1 on emissions sources demonstrate the importance of these source categories.

[122] *See* ENERGY INFO. ADMIN., U.S. DEP'T OF ENERGY, INTERNATIONAL ENERGY OUTLOOK 2008, at 93 fig.77 (Mexico), 94 fig.79 (Asian countries) (2008). All data are country-specific, except for Indonesia, which reflects "Other Asia."

[123] INT'L ENERGY AGENCY, WORLD ENERGY OUTLOOK 2008 FACT SHEET: GLOBAL ENERGY TRENDS (2008), *available at* http://www.worldenergyoutlook.org/docs/weo2008/fact_sheets_08.pdf. As Posner and Sunstein note based on country-level GHG data, "[i]t should be clear, from these figures, why developing countries are most unlikely to be sympathetic to an approach that allocates emissions rights on the basis of existing emissions levels." Posner & Sunstein, *Per Capita*, *supra* note 18, at 61.

FIGURE 1. 2004 CO_2EQ EMISSIONS BY SECTOR[124]



Much of the focus of emissions reduction strategies to date has been on industry, energy supply, and transport, which comprise roughly two-thirds of all 2004 CO_2eq emissions. According to the IPCC data presented in Figure 1, however, agriculture and forestry emissions contributed roughly 30% of global emissions in 2004.[125] These emissions arise from agricultural practices and deforestation in developed and developing countries. Deforestation is a particular concern in Brazil, Indonesia, and several other developing countries. Forestry and agricultural emissions are influenced not only by practices in developing countries but also by consumption patterns in developed countries.[126] Individual and household emissions are distributed among the energy supply, buildings, and transport sectors on Figure 1, but they, too,

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[124] IPCC AR4 WG III, *supra* note 7, at 29 fig.TS.2b.

[125] *Id.*; William Boyd, *International Forest Carbon and Climate Governance: Current Status and Prospects*, *in* DEFORESTATION AND CLIMATE CHANGE: REDUCING CARBON EMISSIONS FROM DEFORESTATION AND FOREST DEGRADATION (Valentina Bosetti et al. eds., forthcoming 2010) (manuscript at 1, on file with the Harvard Environmental Law Review) (noting "mounting evidence that we cannot stabilize atmospheric CO_2 at a safe level without addressing emissions from the forest sector").

[126] *See* Thomas Wiedmann et al., *Examining the Global Environmental Impact of Regional Consumption Activities — Part 2: Review of Input-Output Models for the Assessment of Environmental Impacts Embodied in Trade*, 61 ECOLOGICAL ECON. 1, 15–16 (2007).

are likely to be important, and recent studies of black carbon or soot suggest that they may be far more important than previously recognized.[127]

Even putting aside the black carbon emissions from the household sector, achieving global GHG reductions of 50% or more will be very difficult if agriculture, forestry, and other land uses are not included in the remedial measures. Given that agriculture and forestry comprise over 30% of the total, achieving emissions reductions in the 80% or greater range may be impossible without reductions from these sectors.[128] At the same time, emissions associated with these sectors are often omitted from climate policy architectures.[129]

4. *Poverty Alleviation*

A fourth test of the plausibility of proposed policy architectures is to examine the means by which they address poverty alleviation. As discussed above, the five largest GHG-emitting developing countries are critical to the success of any climate policy architecture. All have large populations in poverty. According to World Bank data, the percentage of individuals living on less than two dollars a day are 36% in China, 76% in India, 18% in Brazil, 54% in Indonesia, and 5% in Mexico.[130] It is unlikely that these countries will agree to carbon emissions that make poverty worse, and inducing their participation in a climate change agreement may require a reasonable prospect that some measure of poverty alleviation will occur. In short, there will be no solution to climate change without these major developing nations, and little chance of participation by them without the prospect for substantial poverty alleviation.[131]

A common approach is convergence: the rich countries contribute to the economic development of the poor countries to enable the two groups to converge on some intermediate level of capita emissions. But if the two ton per capita emissions level is to be achieved by 2050, the convergence must occur quickly. It also must be followed by prompt joint reductions at remarkable levels.

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[127] *See* Michael P. Vandenbergh & Anne C. Steinemann, *The Carbon-Neutral Individual*, 82 N.Y.U. L. REV. 1673, 1691–95 (2007); V. Ramanathan & G. Carmichael, *Global and Regional Climate Changes Due to Black Carbon*, 1 NATURE GEOSCIENCE 221, 221–22 (2008) (noting that black carbon, or soot, is emitted from cooking and crop residue burning, and concluding that emissions of black carbon result in 55% of the radiative forcing of CO_2 and contribute more forcing than any GHG other than CO_2); *see also* Elisabeth Rosenthal, *Soot from Third-World Stoves Is New Target in Climate Fight*, N.Y. TIMES, Apr. 16, 2009, at A1 (noting that black carbon is second only to CO_2 in its global warming effects).

[128] *See* Stern, *supra* note 7, at 7.

[129] *See, e.g.*, Bosetti et al., *supra* note 4, at 6–7 (discussing cap and trade scheme without REDD).

[130] WORLD BANK, *supra* note 117, at 19–20 tbl.S.2.

[131] If global emissions must be reduced by 50% or more, the rest of the world would have to approach zero emissions just to allow these five developing countries, which currently emit nearly 30% of total emissions, to continue to emit at current levels, much less increase emissions to fuel economic growth. *See* WRI-CAIT, *supra* note 16.

A second approach is to assume that emissions reductions should not prevent increases in per capita income up to some minimum level. An example is the GDR approach developed by EcoEquity and the Stockholm Environment Institute, which excludes populations in any country below $7500 in per capita income from calculations of responsibility and capacity for emissions reductions. Excluding these populations, however, may miss opportunities for initiatives that reduce emissions and enhance the well-being of people in poverty. For example, switching to improved cook stoves will reduce black soot emissions and ill-health effects. Similarly, enabling increases in income to the $7500 level without attending to GHG emissions effects may lead to substantial new GHG emissions from increased production and consumption of consumer goods.

Is it possible to alleviate poverty by increasing per capita income without exceeding climate targets? We examined recent trends in China and India to provide an initial insight into changes in energy-using behavior as incomes increase. In particular, we reviewed recent appliance adoption and usage rates in developing countries for individuals with increased incomes to create a mix of items that many households in developing countries have acquired given the economic wherewithal and access to electricity (see Table 3). In China, these included lights, TVs, washers, fans, DVD players, and refrigerators.[132] Indian households have readily adopted lights and fans, then opted for TVs, refrigerators, and water heaters.[133] Studies suggest that even a small increase in household income can have a significant impact: an urban Indian household whose monthly spending power increases from 300 rupees ($6 USD) to 600 rupees ($12 USD) goes from a 50% likelihood to a 100% likelihood of owning a fan, and from a 25% to a 50% likelihood of owning a TV; at 1700 rupees ($33 USD) per month, half of these households also have a refrigerator.[134] We do not claim that increases in per capita in-

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[132] On average, 420 lights, 102 color TVs, 64 washers, 59 fans, 44 DVD players, and 28 refrigerators were owned for every 100 households in China in 2005. He Yongxiu et al., *Residential Load Forecast in China* 688 tbl.2 (2007) (Eighth International Power Engineering Conference), *available at* http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4510114&isnumber=4509990.

[133] Virginie E. Letschert & Michael A. McNeil, Coping with Residential Electricity Demand in India's Future 6 figs.3 & 4 (2007), *available at* http://eetd.lbl.gov/ea/ies/iespubs/63199.pdf. A study of older data showed similar statistics, including those for lighting. *See* Rangan Banerjee et al., *Electricity Demand for Village Electrification* 2 tbl.1, 3 fig.2 (proceedings of National Renewable Energy Conference, ITT Bombay, 2000), *available at* http://www.me.iitb.ac.in/~rangan/publication/Papers_Proceedings/nrecpaper2.pdf.

[134] Letschert & McNeil, *supra* note 133, at 6 fig.3 (estimates from graph). Note that though adopting TVs before more utilitarian appliances may seem counterintuitive, this consumption pattern is common. *See* Zhao Rong & Yang Yao, *Public Service Provision and the Demand for Electric Appliances in Rural China*, 14 China Econ. Rev. 131, 131 (2003); *see also* Michael Sivak, *Potential Energy Demand for Cooling in the 50 Largest Metropolitan Areas of the World: Implications for Developing Countries*, 37 Energy Pol'y 1382, 1382–83 (2009) (noting that "increasing personal income is likely to lead to an unprecedented increase in energy demand in many developing countries. For example, the potential cooling demand in metropolitan Mumbai [a city with 18.2 million people] is about 24% of the demand for the entire United States").

come in the future will generate the same pattern of consumer behavior as has occurred recently in China and India, or that individuals in China and India have a lesser right to a television or refrigerator than people in developed countries. Rather, we point out that if income growth has the effect it has had recently in China and India, substantial increases in GHG emissions will occur, and these increases need to be accounted for in policy architectures.

TABLE 3: A SAMPLE OF COMMON RESIDENTIAL APPLIANCES IN DEVELOPING COUNTRIES[135]

Appliance	Avg. Hours per day	Months per year in-use	Watts per Hour	Qty	Total kWh per Year	Annual MBtu	$MtCO_2$ at present intensity	$MtCO_2$ at future intensity
Most prolific appliances								
Fluorescent light bulb	5.5	12	15	3	90	0.3	0.15	0.13
Fan	10.0	12	80	1	292	1.0	0.49	0.43
Color TV	6.4	12	125	1	288	1.0	0.48	0.43
Refrigerator	24.0	12	100	1	359	1.2	0.60	0.53
Mobile phone charger	3.5	12	7	1	9	0.0	0.01	0.01
Total					**1038**	**3.5**	**1.73**	**1.54**

The World Bank estimates that 2.6 billion people are living on less than $2 per day,[136] which we estimate to constitute roughly 530 million households.[137] If each of these households were to adopt the items in the sample basket of appliances identified in Table 3, the result would be an additional

[135] Estimated use based on data from the studies in LETSCHERT & MCNEIL, *supra* note 133, as well as R. Saidur et al., *Energy and Associated Greenhouse Gas Emissions from Household Appliances in Malaysia*, 35 ENERGY POL'Y 1648, 1650 tbls.1 & 2 (2007). Power demand for appliances was also calculated based on a sample of appliances available at Compare India, http://CompareIndia.in.com/ (last visited Apr. 14, 2009) (on file with Harvard Environmental Law Review). For a recent study of CO_2 emissions from consumption in China, see Glen P. Peters et al., *China's Growing CO_2 Emissions — A Race Between Increasing Consumption and Efficiency Gains*, 41 ENVTL. SCI. & TECH. 5939, 5940 (2007) (concluding that Chinese CO_2 emissions from urban households and other consumption have outpaced gains from efficiency).

[136] WORLD BANK, *supra* note 117, at 11 tbl.3.

[137] The total of 530 million households is based on population figures in WORLD BANK, *supra* note 117. A regionally-weighted average family size of 4.84 was calculated using statistics for China, India, and parts of Sub-Saharan Africa, which represent the majority of populations living on less than $2 per day. The totals on a per-country basis include China, estimated median household size of 3.7, based on a 2002 average of rural and urban households. ALBERTO NOGALES, WORLD BANK, CHINA: TRANSPORT SECTOR BRIEF, at app. "Transport Sector Measures" (2004), *available at* http://www.worldbank.org/transport/transportresults/regions/eap/eap-china-output.pdf. India has an estimated median household size of 5.8, using "demographics of the poor." Rinku Murgai & Martin Ravallion, *Is a Guaranteed Living Wage a Good Anti-Poverty Policy?* 13 (World Bank Policy Research Working Paper, WPS 3640, 2005), *available at* http://www-wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/2005/06/16/000016406_20050616103635/Rendered/PDF/wps3640.pdf. Zambia has an estimated median household size of 5.3 and was used as a substitute for much of sub-Saharan Africa. WORLD BANK, REPORT NO. 32573-ZM, ZAMBIA POVERTY AND VULNERABILITY ASSESSMENT 68 tbl.3.1 (2007), *available at* http://www-wds.worldbank.org/external/de-

550 terawatt hours of energy demand, and 814 $MMtCO_2$ of expected carbon emissions.[138] This is not a normative statement about whether such consumption is unjust by some global measure; by comparison, electricity consumption in U.S. residences totaled 904 $MMtCO_2$ in 2007.[139]

The implication is that we cannot ignore the need to focus on how those in developing countries can achieve commensurate levels of well-being through activities that generate substantially less GHG emissions. The total new emissions from the sample basket of appliances represent 4% of the allowable global emissions in 2050 if we assume that global emissions must be reduced by 50% from year 2000 levels.[140] As an independent country, this would be the eighth largest polluter, ahead of Canada.[141] Thus, if per capita income generates comparable increases in purchases of consumer goods to those that have occurred in China and India in recent years, in the absence of major technological advances, the result will be a major new source of GHG emissions.

5. *Summary*

To summarize the argument thus far, the conventional approaches to climate change and poverty make one or more of the following assumptions: (1) emissions reductions can be set at levels that will generate a high likelihood that the 2°C temperature target will not be met; (2) revolutionary technologies can be developed and deployed that will dramatically reduce emissions; (3) governance measures can direct limited attention to the agriculture, forestry, land use, and individual and household sectors; (4) developing countries can be induced to participate through emissions targets that are lenient and that do not require reductions from business as usual for many decades; and (5) poverty concerns can be addressed through incentives that will increase per capita income. To protect against the substantial chance that one or more of these assumptions turns out to be unfounded, we suggest that the conservative approach is to use near-term reductions to buy time not only for technological change, but also for the development of more transformative policy architectures and initiatives.

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fault/WDSContentServer/WDSP/IB/2007/10/04/000020439_20071004094458/Rendered/PDF/325730ZM.pdf.

[138] Emissions intensity of 1.48 metric tons of CO_2 per MW based on an average of future energy intensity in China (1.45 metric tons of CO_2 per MW) and India (1.51 metric tons of CO_2 per MW) using data from Carbon Monitoring for Action ("CARMA"), http://carma.org/dig (last visited Apr. 26, 2009) (on file with the Harvard Environmental Law Review). CARMA data were converted at a rate of 0.907 metric tons per short ton.

[139] According to the EIA *Emissions of Greenhouse Gases Report*, electricity, as a subset of residential sector energy consumption, accounted for the emission of 903.7 metric tons of carbon dioxide in the United States in 2007. ENERGY INFO. ADMIN., EMISSIONS OF GREENHOUSE GASES REPORT (2008), http://www.eia.doe.gov/oiaf/1605/ggrpt/carbon.html#residential (on file with the Harvard Environmental Law Review).

[140] Percentage figure based on a global total of 38,984.6 $MMtCO_2$ for the year 2000, which excludes land-use change. *See* WRI-CAIT, *supra* note 16.

[141] *Id.*

II. A Different Path

Many questions arise if the policy architecture must address climate change and social justice without the aggressive assumptions that are explicit or implicit in current proposed architectures. We do not have answers to these questions, but we offer proposed core characteristics to set the landscape for the debate. We also identify examples of policy initiatives that demonstrate the direction that a more transformative approach may take. Governments may decide that the fundamental changes necessary to achieve the 2°C temperature target are not worth the cost, or they may be unwilling or unable to develop a policy architecture that is politically acceptable, but these decisions should be based on informed politics.

A. *Core Characteristics*

We begin by proposing a number of core characteristics of macro-transformation and then turn to examples of the types of initiatives that new policy architectures should seek to promote. These characteristics are not meant to displace the widely adopted notions that the climate policy architecture should be just, "scientifically sound, economically rational, and politically pragmatic."[142]

Priority and Urgency. At the outset, scholars and policymakers should give development of transformative policy architectures the priority and urgency suggested by the analysis in Part I. The development of these policy architectures will take years and will involve difficult local, national, and global discussions. In addition, lock-in effects will occur in the meantime. Every new World Bank-subsidized coal-fired power plant, even if it is more efficient than other coal-fired plants, locks in many decades of GHG emissions, reduces incentives to sign on to a post-Kyoto treaty, induces greater demand for electricity, and, by providing cheap but dirty energy, undermines incentives for development and deployment of alternative sources of energy and less energy-intensive development paths.[143] The longer we wait, the more these lock-in effects will occur.[144]

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[142] Aldy & Stavins, *supra* note 2, at 1.

[143] *See, e.g.*, Lesley Wroughton, *World Bank Approves Funds for Coal-Fired Power Plant*, Reuters AlertNet, Apr. 8, 2008, http://www.alertnet.org/thenews/newsdesk/N08412737.htm (on file with the Harvard Environmental Law Review) (discussing International Finance Corporation ("IFC") funding of the Ultra Mega plant, and noting that it will be more efficient than many coal-fired power plants in India); Dot Earth, Money for India's "Ultra Mega" Coal Plants Approved, http://dotearth.blogs.nytimes.com/2008/04/09/money-for-indias-ultra-mega-coal-plants-approved/ (Apr. 9, 2008) (noting that the Ultra Mega plant will emit 23 million tons of CO_2 per year, but that "[t]he I.F.C., along with the Asian Development Bank, Korea, and other backers, sees the need to bring electricity to one of the world's poorest regions as more pressing than limiting carbon dioxide from fuel burning").

[144] In addition, if developing countries achieve poverty alleviation using the fossil-fuel intensive path taken by developed countries, when they turn to calculate the costs and benefits of making emissions reductions several decades down the road, the costs will be much higher than if the lock-in effects were minimized along the way.

Transformation. Despite the magnitude of the challenge, scholars and policymakers should not shy away from proposing transformative architectures and initiatives. Successful new approaches are unlikely to emerge from any one discipline; rather, they will require active collaboration among economists, other social scientists, emissions experts, and law and policy experts. Part of the answer must be in how the question is framed in the developing world. If it is "Do we have the same right to fossil-fuel based industrialization and household consumption that developing countries had?," it is hard to argue that the answer is no.[145] Public subsidies for coal-fired power plants and for inexpensive, efficient, but numerous new motor vehicles reflect this approach.[146] Yet the approach has the effect of abandoning of the 2°C goal. If the question is framed as "Do you want to make the same jump to a post-industrial society that the developed countries are making, and skip the intermediate stage that the developed countries are trying to move away from?," it is likewise harder to argue that the answer is no.

The problem, of course, is that no one knows whether poverty alleviation and the GHG emissions reductions necessary to attain the 2°C temperature target can be achieved by a leapfrog approach in developing countries. Can poverty and carbon emissions goals be achieved through combining large, industrial-scale innovations with small-scale, but widespread, approaches? Can a focus on developing and deploying new and existing technologies reduce the need for major new coal-fired electric power plants? How can incentives be created for funding small-scale, but widespread, supply and demand solutions, not just conventional, large-scale, energy supply projects? Can better land use, transportation planning, and technological developments substitute for hundreds of millions of new gas-powered cars in India? We do not claim to know. We only claim that many current policy architectures, which appear to assume that developing countries must pass through the traditional industrialization and consumption stage, have a troubling likelihood of allowing catastrophic climate change to occur and of leaving developing countries perpetually behind developed countries. We argue that more attention should be directed toward developing policy architectures and initiatives that will make the shift from a pre-industrial to a post-industrial economy possible without a fossil fuel-driven interim stage.

Existing Policy Architectures and Initiatives. Climate policy architectures and initiatives should supplement, not replace, existing public governance measures. Existing and proposed international and regional public governance schemes (e.g., cap-and-trade schemes and carbon taxes), will continue to be an essential component of any global GHG emissions strategy. These measures will raise the price of GHG emissions, which will have

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[145] *See* Posner & Sunstein, *supra* note 1, at 1602.

[146] *See, e.g.*, Sunita Narain, Editorial, *The Right Right*, DOWN TO EARTH, Apr. 15, 2009, *available at* http://www.downtoearth.org.in/editor.asp?foldername=20090415&filename=Editor&sec_id=2&sid=1 (discussing subsidies for the Nano car and the need to reframe arguments about rights to modern transportation).

important effects in the developed and developing worlds. Although more transformative steps are needed, the transformative steps will not be a substitute for the conventional approaches, and the need for transformative approaches should not be used to delay or dilute the conventional ones. At the same time, international, regional, and national cap-and-trade, carbon tax, and other schemes should not undermine efforts to generate deeper change. In particular, it is important to recognize that any macro-transformation attempt by a smaller economy could be undermined by actions in large economies.[147]

Expanded Portfolio of Architectures and Initiatives. The more transformative approach will require a level of law and policy innovation comparable to the one that occurred two decades ago, launching the current focus on cap-and-trade and carbon tax solutions.[148] It may be that a single concept comparable to increasing the price of carbon will emerge to meet this need. It is also possible that a basket of approaches will be necessary, and that the only unifying concept will be that emissions that are largely beyond the reach of carbon prices will be reduced by many of these new approaches. The GHG emissions problem resembles the sulfur dioxide-driven acid rain problem in many ways, but GHG emissions are far more deeply entwined with the full range of consumption and production, and many of these activities are less sensitive to price signals than are sulfur dioxide emissions. Scholars and policymakers certainly will not be starting from scratch. Evaluation of ongoing efforts within carbon finance markets, especially those that also include non-carbon social benefits, such as those targeted at "reducing emissions through deforestation and degradation" ("REDD") or "payment for eco-system services" ("PES"), have taught us a great deal about how both micro-innovations and macro-transformational initiatives can succeed and how they can go wrong.[149]

Transformative policy architectures also should reflect the need to provide incentives in the developed and developing worlds for changes in consumption patterns.[150] Pricing carbon through a cap-and-trade scheme or a

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[147] For example, according to the World Bank, if measures of poverty took into account the increase in food prices, global estimates in 2009 "might show a reversal of the steady decline in poverty rates of the previous few years." For many, the fall below poverty can be traced to changes in global food prices due to biofuel policies in the United States and Europe. WORLD BANK, WORLD BANK DEVELOPMENT REPORT 2010: DEVELOPMENT IN A CHANGING CLIMATE: CONCEPT NOTE 6 (2008).

[148] *See, e.g.*, Bruce A. Ackerman & Richard B. Stewart, *Reforming Environmental Law*, 37 STAN. L. REV. 1333 (1985) (proposing a cap-and-trade approach for stationary air pollution sources).

[149] *See* LEO PESKETT ET AL., POVERTY ENVIRONMENT PARTNERSHIP REPORT: MAKING REDD WORK FOR THE POOR 5 (2008); ARILD ANGELSEN ET AL., REDUCING EMISSIONS FROM DEFORESTATION AND FOREST DEGRADATION (REDD): AN OPTIONS ASSESSMENT REPORT (2009), *available at* http://www.redd-oar.org/links/REDD-OAR_en.pdf; Larry Lohmann, *Carbon Trading: A Critical Conversation on Climate Change, Privatisation and Power*, 48 DEV. DIALOGUE 5 (2006).

[150] *See generally* Douglas A. Kysar & Michael P. Vandenbergh, *Introduction: Climate Change and Consumption*, 38 Envtl. L. Rep. News & Analysis (Envtl. Law Inst.) 10,825

carbon tax will push incentives in this direction, but price alone may not affect many types of consumption that are carbon-relevant, such as when an activity does not involve the transfer of money, when information about how to save money is unavailable, or when the infrastructure for low-cost, low-emission behaviors does not exist.[151] Pricing strategies may run into particular limitations in the agriculture, forestry, land use, and individual and household sectors in both developing and developed countries. In addition, cap-and-trade schemes should be carefully designed to reduce incentives for leakage from developed to developing countries as developed world consumption is satisfied by developing world production.[152] Studies have demonstrated significant shifts in the most carbon-intensive production to developing countries in recent years, and a recent study concluded that roughly one-third of China's GHG emissions arise from the production of goods for export.[153]

Expanded Portfolio of Sectors and GHGs. The Part I analysis suggests that the types of sectors that are likely to be only modestly affected by traditional price-based measures (e.g., agriculture, forestry, other land use, and individuals and households) make up a large share of the total GHG emissions inventory, particularly in developing countries. It may be impossible to achieve the necessary reductions by 2050 without these sectors, and even if it is possible to achieve those reductions, it may be more expensive to treat them as less important than the traditional industrial and transportation sources. In both developed and developing countries, price-based laws and policies targeted at large industrial sources and transportation fuels should be supplemented with approaches that address the non-traditional sectors. In addition, all six of the GHGs identified in the Kyoto Protocol should be included in the emissions reduction strategies, and other substances added as necessary. Many types of GHG emissions other than CO_2 are common from the sectors that play a strong role in the developing countries. Examples include emissions from agriculture (e.g., methane and nitrous oxide) and household cooking and heating (e.g., black carbon).

Poverty Alleviation. The analysis in Part I suggests that poverty alleviation is essential to catastrophic climate change risk reduction. Successful transformative policy architectures will strive to achieve both of these goals. Wherever possible, poverty alleviation should be achieved through approaches that reduce GHG emissions, or at worst hold GHG emissions con-

(2008) (discussing the importance of examining the relationship between consumption and GHG emissions).

[151] *See, e.g.*, Vandenbergh & Steinemann, *supra* note 127, at 1715–16 (discussing limits of price signals on individual environmentally significant behaviors).

[152] *See* Vandenbergh, *supra* note 22, at 911, 945–46.

[153] Christopher L. Weber et al., *The Contribution of Chinese Exports to Climate Change*, 36 ENERGY POL'Y 3572, 3574 (2008) (estimating that one-third of Chinese CO_2 emissions arise from production of goods for export); *see also* Bin Shui & Robert C. Harriss, *The Role of CO_2 Embodiment in US-China Trade*, 34 ENERGY POL'Y 4063, 4066 (2006) (estimating that Chinese exports to the United States account for 7 to 14% of Chinese CO_2 emissions from 1997 through 2003).

stant. Approaches that attempt to alleviate poverty through transfers (or side payments) rather than structural transformation should be used sparingly, and only after approaches that consider the relationships among poverty-related and climate-related behaviors. Both small-scale innovations and macro-transformations have the potential to affect the structures that perpetuate poverty or to focus merely on redistribution.

Measures of Well-Being. A transformative approach should measure poverty alleviation not only with traditional per capita income measures, but also with measures that account for improvements in well-being. The growing literature on happiness and well-being suggests that income has limitations as a proxy for well-being, and that the use of income as a metric may lead to policies that generate higher levels of GHG emissions than would occur if broader measures were used. Although increases in income are associated with increases in happiness or well-being at low income levels, the relationship weakens as income increases, and even for low-income individuals, income is an incomplete measure of well-being.[154]

The factors associated with increased well-being that are not captured by changes in per capita income may be particularly important for joint efforts to alleviate poverty and reduce GHG emissions in developing countries. In developing countries, a larger proportion of consumption and labor takes place without monetary transfers, making the impact of income on well-being difficult to measure. For example, when incomes rise through paid employment, domestic labor burdens shift to those not in the formal work place.[155] This production includes care work, but also home-based production such as agriculture and rice processing. With such shifts, children (girls more so than boys) are drawn out of school. The net impact on the well-being of each family member cannot be measured by the increase in household income. By contrast, when farmers shift from purchased seeds and fertilizers to sustainable methods that use composting, health improves as families are less exposed to fertilizers spread by hand and runoff in their water supplies. The increases in well-being may not be accounted for in measures of net income. Studies also indicate that the success of poverty alleviation initiatives, and thus well-being, is affected by the degree to which the poor participate in the political and social processes used to develop the

[154] *See, e.g.*, Mark A. Cohen & Michael P. Vandenbergh, *Consumption, Happiness, and Climate Change*, 38 Envtl. L. Rep. (Envtl. Law Inst.) 10,834, 10,835–37 (2008) (reviewing the happiness literature); AMARTYA SEN, DEVELOPMENT AS FREEDOM (1999) (discussing human capabilities). For a discussion of the multidimensionality of capability and its measurement, see Sabina Alkire & James Foster, *Counting and Multidimensional Poverty Measurement* (Oxford Poverty & Human Dev. Inst., Working Paper No. 7, 2008), *available at* http://www.ophi.org.uk/pubs/OPHI_WP7.pdf.

[155] The connections between formal and informal labor and well-being have been explored in a vast literature beginning in the 1980s. *See* Lourdes Benería & Gita Sen, *Class and Gender Inequalities and Women's Role in Economic Development: Theoretical and Practical Implications*, 8 FEMINIST STUDIES 157, 160–76 (1982); MARTHA CHEN ET AL., PROGRESS OF THE WORLD'S WOMEN 2005: WOMEN, WORK AND POVERTY ch. 4 (2005).

initiatives.[156] Other examples of areas where improvements in well-being may not be closely associated with increases in income and GHG emissions are health, leisure, and education.[157]

Increases in well-being can be either underestimated or overestimated by focusing exclusively on per capita income.[158] Allocations of emissions reduction benefits and burdens that use per capita income but do not account for well-being may miss opportunities to account for and stimulate the development of low-GHG initiatives while improving well-being. Allocations that assume that poverty must be alleviated (and developing countries must be given incentives) through increased per capita income thus may induce greater GHG emissions per increase in well-being than allocations that use a broader metric. In short, transformative approaches are more likely to occur if changes in well-being arising from non-monetized labor and consumption are accounted for in climate policy architectures.

We assume that any transformative policy architecture will reflect these core considerations and will stimulate a wide range of more specific private and public governance initiatives. Given the importance of the countries and sectors that will be difficult to include in a more conventional policy architecture, we suggest that scholars and policymakers devote as much time and effort to developing proposed transformative architectures and initiatives as they are now giving to the more conventional approaches.

B. *Short-Term Initiatives*

To be plausible, any move toward a transformative policy architecture must be able to point to concrete, feasible initiatives. Although we have only sketched the initial outlines of a transformative approach, a number of concrete examples demonstrate that the approach can yield viable initiatives. In Part II.B, we discuss a near-term, private market initiative, and in Part II.C we discuss longer-term initiatives. Our proposed private market initiative involves the addition of equity micro-offsets ("EMOs") as an extension of the growing retail carbon offset market. A few examples of EMOs exist today, and expansion of the private market for EMOs could result in prompt, substantial carbon emission reductions while improving the well-being of the most disadvantaged populations in developed and developing coun-

[156] Sabina Alkire, *Subjective Quantitative Studies of Human Agency*, 74 SOC. INDICATORS RES. 217 (2005) (offering an empirical approach to the quantitative study of human agency).

[157] *See* Cohen & Vandenbergh, *supra* note 154, at 10,835–37.

[158] The conception of well-being we use is amenable to estimating the monetary equivalence of changes in well-being that are conferred through non-market labor and consumption. For an example of efforts to improve measures of well-being, see Amartya Sen, *Well-Being, Agency and Freedom: The Dewey Lectures*, 82 J. PHIL. 169 (1985) (setting out the importance of attending to well-being and agency); SABINA ALKIRE, VALUING FREEDOMS: SEN'S CAPABILITY APPROACH AND POVERTY REDUCTION (2002) (offering an empirical approach to measuring capability). Our approach could accommodate these efforts but does not depend on them.

tries.[159] By linking the purchasers, developers, principals, and benefactors of carbon projects with the growing microfinance community, it may be possible to develop a large, active private EMO market. In addition, over the longer term the private EMO market could be folded into cap-and-trade programs at the national and international levels.

1. *Existing Carbon Markets*

The size and scope of the existing carbon credit market demonstrates the potential for EMOs. In 2007, global markets traded nearly 3000 million metric tons of carbon dioxide equivalent ("$MMtCO_2eq$") credits.[160] Trading increased to 4000 $MMtCO_2eq$ in 2008.[161] Trading volume includes credits exchanged multiple times and covers a range of vintages (the year in which the associated credit was generated), but this figure represents around 10% of global emissions attributable to anthropogenic sources, recently estimated at 43,000 $MMtCO_2eq$ per year.[162]

Credits are traded for both regulatory compliance and voluntary objectives. Although compliance accounts for the overwhelming majority of activity, voluntary markets are growing dramatically, representing more than 2% of total volume traded in 2007.[163] Voluntary transactions take place both on formal exchanges such as the Chicago Climate Exchange ("CCX") and over-the-counter ("OTC"). In 2007, roughly 65.0 $MMtCO_2eq$ were exchanged in the voluntary market: 22.9 $MMtCO_2eq$ via the CCX, and 42.1 $MMtCO_2eq$ OTC. These figures correspond to $330.8 million in value.[164] When a voluntary credit is permanently taken off the market, or "retired," it effectively functions as a carbon offset. About one-quarter of the credits traded OTC in 2007 were confirmed as permanent offsets.[165] In 2007, the average price for OTC credits sold in the United States (denominated in short tons instead of metric tons) was $6.10.[166]

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[159] *See* Vandenbergh & Ackerly, *supra* note 1, at 75–76 (discussing domestic equity offsets); Ackerly & Vandenbergh, *supra* note 1, at 565 (discussing a global role for equity offsets).

[160] KATHERINE HAMILTON ET AL., THE KATOOMBA GROUP'S ECOSYSTEM MARKETPLACE, FORGING A FRONTIER: STATE OF THE VOLUNTARY CARBON MARKETS 2008, at 7 (2008), *available at* http://ecosystemmarketplace.com/documents/cms_documents/2008_StateofVoluntaryCarbonMarket.4.pdf.

[161] Press Release, New Carbon Fin., Carbon up 84% in 2008 at $118b (Jan. 8, 2008) *available at* http://newcarbonfinance.com/download.php?n=20090108_PR_Carbon_Markets_Q42008.pdf&f=fileName&t=NCF_downloads.

[162] Total is based on 2005, the most recent year with complete data. WRI-CAIT, *supra* note 16.

[163] *See* HAMILTON ET AL., *supra* note 160, at 26 tbl.2.

[164] *Id.* The total includes $72.4 million CCX and $258.4 million OTC. *Id.* Preliminary data indicate that transactions in the voluntary market rose to $499 million in 2008. Press Release, New Carbon Fin., *supra* note 161.

[165] Of the 42.1 MMtCO2eq of credits traded on the OTC market in 2007, respondents were only able to confirm that 10.7 MMtCO2eq were directly destined for retirement. HAMILTON ET AL., *supra* note 160, at 6.

[166] *See id.* at 29. Prices for carbon credits vary significantly based on the source of emission reduction (e.g. forestation, methane capture, energy efficiency), the standard the credit is

Several segments of the voluntary carbon market already factor in social justice considerations when developing carbon credits, including the CDM Gold Standard and Social Carbon. These represent 9% and 2%, respectively, of the voluntary carbon offset market.[167] The CDM Gold Standard ("GS") is a private non-profit group with no official ties to the UNFCCC Clean Development Mechanism ("CDM"). It functions as a foundation, a method for developing carbon projects, and as a label that can be applied to projects adhering to specific guidelines for sustainable development. For example, the GS will award a quality label to a UNFCCC-sanctioned CDM project that meets specific criteria and goes through the GS certification process. The GS also certifies voluntary credits developed using its methodology. The GS gives explicit consideration to sustainability issues as part of the certification process.[168]

Social Carbon is a second private standard that accounts for social justice. Its methodology involves a community-level assessment of six resource classes: carbon, biodiversity, social, financial, human, and natural.[169] To measure and continually improve overall sustainability, Social Carbon rates the impact on each of these resources on a scale of one to six every year over the life of the project.[170]

Both the CDM Gold Standard and Social Carbon credits command a substantial premium in the market. For example, in 2007 and 2008, Gold Standard credits sold for more than twice the price of the average voluntary carbon credit.[171] Although further study will be required to establish the causes of the price premium, the premium may indicate that buyers place a substantial value on offsets that address social justice issues as well as GHG emissions. Buyers also may believe that these credits and their standards have a greater likelihood of being incorporated into future compliance markets.[172]

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based on (e.g. CDM VER, VCS, etc.), as well as normal supply/demand dynamics. A participant's position in the supply chain (e.g. developer, wholesaler, broker, trader, final buyer) also affects a credit's selling price. *See, e.g.*, U.S. GOV'T ACCOUNTABILITY OFFICE, CARBON OFFSETS: THE U.S. MARKET IS GROWING, BUT QUALITY ASSURANCE POSES CHALLENGES FOR MARKET PARTICIPANTS (2008) (report to congressional requesters), *available at* http://www.gao.gov/new.items/d081048.pdf.

[167] HAMILTON ET AL., *supra* note 160, at 52 fig.22.

[168] THE GOLD STANDARD, ANNEXES TO TOOLKIT, Annex A (2008) (on file with the Harvard Environmental Law Review).

[169] Social Carbon, How it Works, http://www.socialcarbon.com/en/?page=How_It_Works (last visited Apr. 16, 2009) (on file with the Harvard Environmental Law Review).

[170] *Id.*

[171] NEW CARBON FIN., VOLUNTARY CARBON INDEX (VCI) 2 (2008), *available at* http://newcarbonfinance.com/download.php?n=NCF_NA_VoluntaryCarbonIndex_2008_082.pdf&f=FileName&t=NCF_downloads.

[172] *Id.* (noting "demand from pre-compliance buyers willing to pay above average prices").

2. *Evaluating and Quantifying Social Justice*

Just as carbon offset projects are vetted to ensure that their contribution improves the business-as-usual scenario in terms of GHG emissions, projects should be assessed to ensure that they result in a net social justice improvement.[173] Development of market-worthy EMOs will be difficult without rigorous evaluations of effectiveness. Many methodologies have been developed to quantify GHG emissions reductions by comparing a baseline case with a project's end results,[174] but measuring the results of a social justice improvement can be difficult. Justice improvements are often context-dependent.[175] Identifying measurable indicators of social justice improvements is more challenging than weighing a ton of carbon, and the costs of measuring the social justice impacts of small projects could overwhelm the benefits of the offsets or inhibit their pursuit.

Despite the difficulties of assessing social justice, project developers and third party verifiers could make reasonable approximations of improvements relative to established regional targets. A sufficient metric could be as simple as a yes-no qualification decision by the offset creator or third-party certifier, or assignment to one of several broad grade levels of impact.[176] If the market demands quantifiable measures of social justice achievements, programs can be evaluated on a metric of qualitative and quantitative measures that are scaled so that EMO initiatives can be compared for their effectiveness at promoting improvements in social justice (e.g., in ways similar to those deployed by CDM Gold Standard and Social Carbon). Social justice assessments also could be based on the social performance evaluation systems developed for microfinance institutions. For example, the Consultative Group to Assist the Poor, a group of twenty-eight agencies supporting microfinance, created an analysis of households' relative poverty status that can be used to place a household into one of three categories based on its

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[173] *See* Brooke A. Ackerly, *Feminist Theory, Global Gender Justice, and the Evaluation of Grant-Making*, 37 PHIL. TOPICS 2, pts. I & II (forthcoming 2009) (on file with the Harvard Environmental Law Review)

[174] ANJA KOLLMUSS ET·AL., MAKING SENSE OF THE VOLUNTARY CARBON MARKET: A COMPARISON OF CARBON OFFSET STANDARDS (2008), *available at* http://assets.panda.org/downloads/vcm_report_final.pdf.

[175] *See* Ackerly, *supra* note 173 (manuscript at 7–8).

[176] One such scenario would create a social justice credit by comparing improvements to targets established by the Millennium Development Goals ("MDG"). *See* United Nations, Millennium Development Goals 2015, http://www.un.org/millenniumgoals/ (last visited Apr. 26, 2009) (on file with the Harvard Environmental Law Review). For example, if the EMO funds are transferred in the form of a loan to a woman, as is common in microfinance, it could receive direct recognition for its contribution to the MDG of gender equity. Mark M. Pitt et al., *Empowering Women with Micro Finance: Evidence from Bangladesh*, 54 ECON. DEV. & CULTURAL CHANGE 791 (2006); MDG Monitor, Promote Gender Equality and Empower Women, http://www.mdgmonitor.org/goal3.cfm (last visited Apr. 26, 2009) (on file with the Harvard Environmental Law Review) (referring to share of women in wage employment in the non-agricultural sector).

established poverty index.[177] In addition, the Millennium Development Goals developed by the United Nations may contribute to the development of useful poverty alleviation measures for EMOs.[178]

In addition to serving as the basis for an EMO, establishing a common metric for assessing social justice improvements could benefit not only the carbon markets, but also other institutions that interact with and affect the lives of disadvantaged populations. For example, a common metric also could be applied to the efforts of microfinance institutions as they attempt to improve the lives of households in developing countries. A common metric would enable NGOs that concurrently address GHG emissions and social justice (e.g., The Converging World) to boost the level of transparency to donors.[179] Overall, the metric could help reduce bias in the comparison of different activities and perhaps serve as a basis for premiums on certain products when established targets are exceeded.

3. *Equity Micro-Offset Projects*

We envision equity micro-offsets as a mechanism to reduce carbon emissions in parallel with improving social justice. EMOs are carbon credits generated in the process of improving social equity, with the proceeds of selling the credits helping the project to pay for itself.[180] A simplified means to bring EMOs to market could follow the label and endorsement routes

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[177] THE CONSULTATIVE GROUP TO ASSIST THE POOR ("CGAP"), THE POVERTY AUDIT 8 (2003), *available at* http://www2.ids.ac.uk/impact/files/reviews/CGAP_poverty_audit.pdf; *see also* CGAP, Advancing Financial Access for the World's Poor, http://www.cgap.org/ (last visited Apr. 15, 2009) (on file with the Harvard Environmental Law Review). For additional information about social performance assessment tools, see The Microfinance Gateway, MicroFinance Initiatives, Social Performance Assessment Tools, http://www.microfinancegateway.com/resource_centers/socialperformance/article/35397 (last visited April 15, 2009) (on file with the Harvard Environmental Law Review).

[178] *See* United Nations, *supra* note 176; G.A. Res 60/1, U.N. Doc. A/RES/60/1 (Oct. 24, 2005) (resolution revising the eight MDGs); MDG, Official List of MDG Indicators, http://mdgs.un.org/unsd/mdg/Host.aspx?Content=Indicators/OfficialList.htm (last visited Apr. 15, 2009) (on file with the Harvard Environmental Law Review) (noting that MDG goals are to (1) eradicate extreme poverty and hunger; (2) achieve universal primary education; (3) promote gender equality and empower women; (4) reduce child mortality; (5) improve maternal health; (6) combat HIV/AIDS, malaria, and other diseases; (7) ensure environmental sustainability; and (8) develop global partnership for development). For data by series, see MDG Indicators, Data Availability by Series and MDG Region, http://mdgs.un.org/unsd/mdg/DataAvailability.aspx (last visited Apr. 15, 2009) (on file with the Harvard Environmental Law Review). The indicators of the poverty goal do not focus on raising overall GDP per capita, but rather on raising the well-being of the least well off.

[179] The Converging World is an NGO that uses donations to finance wind turbines. Those turbines are used to generate revenue via the sale of electricity and carbon credits, and the profits are donated to the charity Social Change and Development, which applies the funds toward education, health, and environmental projects in the developing world. The Converging World, About Us, http://www.theconvergingworld.org/document_1.aspx?id=0:37374 (last visited Apr. 15, 2009) (on file with the Harvard Environmental Law Review).

[180] *See* Vandenbergh & Ackerly, *supra* note 1, at 68–69; Ackerly & Vandenbergh, *supra* note 1, at 563. Unfortunately, no economically viable methodology exists that will enable generation of carbon credits based on OECD residential energy improvements; the revenue from these credits is relatively insubstantial (based on a potential annual reduction of up to

taken by the Gold Standard and Social Carbon. Current market participants would be encouraged to rate their activities according to accepted methodologies. The incentive for positive ranking may support a premium for their product, and the premium in turn may be used to fund additional projects. Although more research remains to be done, the premium commanded by existing offsets with a social justice component suggests that EMOs may be able to generate a price premium in the carbon credit markets. In addition, the success of organizations such as Global Giving demonstrates that a large market exists for low transaction cost, Internet-driven systems that transfer money from multiple small donors to multiple small-scale projects designed to alleviate poverty in the developing world.[181]

The development of the EMO market could be enhanced by linking it to the growing microfinance movement. Collectively, microfinance institutions have in excess of $25 billion in loans outstanding.[182] A recent study of microfinance institutions and their funding sources indicated this money comes from donations (26%), non-commercial borrowing (11%), equity (13%), commercial borrowing (23%), and deposits (27%).[183] Microfinance institutions make substantial efforts to rate the social performance of their lending,[184] but their measurement schemes do not appear to include GHG emissions impacts. In addition, in the absence of a focus on GHG emissions, microfinance activity can lead to additional carbon emissions.[185] Integrating even a rough GHG assessment into microfinance lending criteria may not only enhance GHG global emissions reduction efforts, but also increase the pool of potential investors. Given the importance of climate change and climate change mitigation costs to the communities served by microfinance institutions, these institutions may become leading investors in EMOs. Carbon projects that generate credits by mitigating industrial gases have been criticized for contributing little in the way of additional social benefits.[186] A linkage between carbon projects and social projects may be mutually beneficial.

Recent initiatives demonstrate the feasibility of projects that could generate EMOs. The first involves ongoing efforts to promote improved cook

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several tons of CO_2eq per house, and a very modest per-ton value of CO_2eq, amounting to less than $30/house/year) and must be combined with other funding sources.

[181] *See* Vandenbergh & Ackerly, *supra* note 1, at 14 & n.59.

[182] DEUTSCHE BANK RESEARCH, MICROFINANCE: AN EMERGING INVESTMENT OPPORTUNITY 7, 18 (2007), *available at* http://www.dbresearch.de/PROD/CIB_INTERNET_EN-PROD/PROD0000000000219174.PDF.

[183] Robert Cull et al., *Microfinance Meets the Market* 34 tbl.4 (World Bank, Policy Research Working Paper No. 4630, 2008), *available at* http://ssrn.com/abstract=1149133.

[184] *See* discussion *supra* note 177.

[185] *See supra* note 134 and accompanying text (noting that increasing income in poor populations in India and China leads to increasing appliance and electricity usage); *see also* Shahidur R. Khandker, *Microfinance and Poverty: Evidence Using Panel Data from Bangladesh*, 19 WORLD BANK ECON. REV. 263, 266 (2005) (noting that "[i]ncome or consumption poverty can be reduced through interventions such as microfinance that help the poor become self-employed and generate income").

[186] *See* KOLLMUSS ET AL., *supra* note 174, at 22.

stoves[187] ("ICSs") by carbon project developers and microfinance groups. We discuss ICSs further in Part II.C, but for our purposes here the key point is that traditional biomass-fueled cooking has several downsides that ICSs could address: it is inefficient and thus generates higher-than-necessary operating costs; it generates large amounts of black carbon, a remarkably important contributor to climate change;[188] and contact with the smoke and ash emissions is linked to significant health issues.[189] EMO project developers could bundle large numbers of ICSs to generate substantial amounts of GHG emissions reductions and social justice benefits.[190] Microfinance institutions could provide the initial capital to facilitate the generation of the offsets.

A second example involves the handling of manure from livestock and poultry, along with other biological wastes. These waste streams yield a substantial amount of methane, a greenhouse gas twenty-one times more potent than carbon dioxide.[191] When fermented, these waste streams can be used as sludge to fertilize crops, and the off-gas can be used as a substitute for wood, agricultural residue, animal dung, or other fossil fuels.[192] Because even small-scale fermenting units can generate biogas and fertilizer that can be sold for a profit, microfinance institutions have extended funding to these types of projects.[193] Carbon project developers also have embraced this pro-

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[187] ICS distribution has been helped by both carbon finance and microfinance. *See, e.g.*, Climatecare, Uganda Efficient Stoves, http://www.jpmorganclimatecare.com/projects/countries/Uganda-efficient-stoves/ (last visited Apr. 19, 2009) (on file with the Harvard Environmental Law Review) (noting role of voluntary carbon finance and microfinance in ICS distribution). A Gold Standard Methodology has been established for carbon credits based on ICS. *See* Gold Standard Foundation, Methodology for Improved Cook-Stoves and Kitchen Regimes V.01, http://www.cdmgoldstandard.org/uploads/file/V01%2010-05-08%20GS%20 Cook-stove%20Methodology.pdf (last visited Apr. 19, 2009) (on file with the Harvard Environmental Law Review).

[188] *See* Ramanathan & Carmichael, *supra* note 127, at 221–22; *see also* Rosenthal, *supra* note 127, at A1, A12 (noting that according to Stanford professor Mark S. Jacobson, it is "bizarre" that black carbon is not a part of proposed policy architectures); JP Morgan, ClimateCare, Uganda Efficient Wood Cook Stoves (n.d.), *available at* http://www.jpmorganclimatecare.com/media/documents/pdf/PIN_Uganda_0015B_Wood%20Stoves.pdf (noting project that "involves the dissemination of efficient wood cook stoves to institutions and families in and around Kampala, Uganda").

[189] *See* Min Bikram Malla et al., Presentation to the 136th Annual Meeting and Expo of the American Public Health Association: Climate Change, Cook Stoves, and Coughs & Colds: Evidence from Rural Nepal on Thinking Global, and Acting Local (Oct. 29, 2008), *available at* http://apha.confex.com/apha/136am/techprogram/paper_185626.htm (reporting that implementing ICS technology led to reductions in PM concentration (10 to 70%), acute respiratory illnesses (10 to 30%), medical costs (10 to 50%), cooking and collection time (20%), fuelwood consumption (25%), and GHG emissions (25%)); *see also* M. I. Howells et al., *A Model of Household Energy Services in a Low-Income Rural African Village*, 33 ENERGY POL'Y 1833 (2005).

[190] Initial activity in this area has already begun. *See* ClimateCare, *supra* note 187.

[191] IPCC AR4 WG I, *supra* note 7, at 212 tbl.2.14.

[192] *See* Guozhu Li et al., *Assessment of Environmental and Economic Costs of Rural Household Energy Consumption in Loess Hilly Region, Gansu Province, China*, 34 RENEWABLE ENERGY 1438, 1441 (2009).

[193] *See* Elizabeth Israel et al., Note from India: Greening Microfinance to Turn Waste Into Wealth, http://www.microlinks.org/ev_en.php?ID=28405_201&ID2=DO_TOPIC (last visited Apr. 19, 2009) (on file with the Harvard Environmental Law Review); *see also* Sunderasan

cess as a means to mitigate GHG emissions.[194] Similar to the dissemination of improved cook stoves, biogas initiatives require initial capital, but they can yield GHG and social justice outcomes.

4. *Integration into Public Governance Schemes*

The voluntary carbon market serves as an example of how private governance that arises in the shadow of a larger regulated compliance market can complement public governance and can test concepts for inclusion in public governance.[195] In the longer run, international, regional, and national cap-and-trade schemes could expand the reach of EMOs by allowing EMOs to satisfy regulatory requirements for allowance-holding.[196]

C. *Long-Term Initiatives*

Equity micro-offsets and other initiatives hold out the prospect for near-term emissions reductions that contribute to improvements in well-being. In the longer term, much more fundamental changes may be needed if the goal is to achieve by 2050 global per capita emissions that are equal to India's two-ton level today. The option that seems to be off the table in current debates is a deeper macro-transformation of the relationship between well-being, material throughput, and carbon emissions on a global scale.[197] Such transformations can be induced by policies directed toward particular sectors, recognizing that these can be interrelated through either production or

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Srinivasan, *Positive Externalities of Domestic Biogas Initiatives: Implications for Financing*, 12 RENEWABLE & SUSTAINABLE ENERGY REVS. 1476, 1478 (2008).

[194] THE GOLD STANDARD FOUND., INDICATIVE PROGRAMME, BASELINE, AND MONITORING METHODOLOGY FOR SMALL SCALE BIODIGESTER: VOLUNTARY GOLD STANDARD (2007), *available at* http://www.cdmgoldstandard.org/uploads/file/GS%20biodigester%20methodology%20301007%20Final.pdf.

[195] For a discussion of the relationship between private and public environmental governance, see Jody Freeman, *The Private Role in Public Governance*, 75 N.Y.U. L. REV. 543, 551–56 (2000); Michael P. Vandenbergh, The *Private Life of Public Law*, 105 COLUM. L. REV. 2029, 2037–41 (2005). A recent example of a movement of a climate governance regime from the private to the public arena is the regulatory adoption by states of reporting protocols established by the California Climate Action Registry, a private non-profit organization. *See* Carbon Positive, CCAR Forest Protocol, http://www.carbonpositive.net/viewarticle.aspx?articleID=1367 (last visited Apr. 26, 2009) (on file with the Harvard Environmental Law Review).

[196] Not surprisingly, a recent comparison of economic agreement structures concludes that distributional justice issues, as measured by income distribution across regions, improves when REDD is added to cap-and-trade, as does efficiency. Bosetti et al., *supra* note 4, at 15 (noting that "the inclusion of avoided deforestation among the mitigation options leads to an improvement in the distribution of income across regions"). Our proposal incorporates REDD concepts, but it goes beyond REDD to include households and small businesses even when their carbon impact is not associated with deforestation or land use.

[197] To change the amount of well-being produced by any GHG-emitting behavior, we need other transformations: economic, financial, infrastructural, and political. See WORLD BANK, *supra* note 147, for emphasis on "political economy considerations and the role of institutions and governance since these issues are more often than not the binding constraints to progress."

consumption, or they can be focused on more structural transformations that affect the carbon footprint of an entire community.[198]

In the housing sector, energy savings and increases in well-being are possible by scaling up the individual cook stove initiatives discussed above. These ICS projects are examples of household-level micro-initiatives that benefit people in poverty by targeting their largest GHG-emitting and highest cost activities. These initiatives substantially reduce household energy use and carbon emissions while improving well-being in a variety of ways that are not captured by changes in per capita income or similar measures.

The potential impact of the cook stove initiative is an average 39% reduction in CO_2eq emissions from domestic cooking in developing regions.[199] Around the world, two billion people rely on wood or charcoal for cooking fuel.[200] Much of the emissions growth that is expected to occur by 2050 will occur in countries with large populations that will otherwise rely on wood or charcoal for cooking.[201] For example, countries most likely to have high demand for improved cook stoves include three of the five biggest current and projected future GHG-emitting countries, India, China, and Brazil.[202] ICSs can be made with inexpensive materials.[203] They are simple to assemble and easy to use. Similarly, more efficient wood and charcoal stoves have achieved CO_2eq emissions reductions of almost 40%.[204]

The most obvious increase in well-being from the switch to efficient cook stoves is savings in time, energy, or money associated with securing adequate fuel. Significant improvements also may occur in health and security. With fuel savings, more people may pasteurize water, which prevents water-borne diseases.[205] Efficient cook stoves also reduce air

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[198] *See, e.g.*, PESKETT ET AL., *supra* note 149 (reviewing the range of transformational impacts of programs for reducing emissions from deforestation and degradation); Ctr. for Org. Research & Educ., *Provisional Agenda Item 3: Special Theme: Climate Change, Bio-Cultural Diversity and Livelihoods: The Stewardship Role of Indigenous Peoples and New Challenges* 2 (2008), *available at* http://www.un.org/esa/socdev/unpfii/documents/E_C19_2008_CRP_5.pdf

[199] Michael Johnson et al., *Quantification of Carbon Savings from Improved Biomass Cookstove Projects*, 43 ENVTL. SCI. TECH. 2456, 2456 (2009); *see also* Solar Cookers International, Where Solar Cook?, http://solarcookers.org/basics/where.html (last visited Apr. 19, 2009) (on file with the Harvard Environmental Law Review). These initiatives can also be targeted at people who are in or near poverty in the developed world as well. Vandenbergh & Ackerly, *supra* note 1, at 61–62.

[200] Solar Cookers International, Why Solar Cook?, http://solarcookers.org/basics/why.html (last visited Mar. 20, 2009) (on file with the Harvard Environmental Law Review).

[201] *See* discussion *supra* notes 120–29 and accompanying text (discussing projected emissions growth in developing countries).

[202] *See* Solar Cookers International, *supra* note 199 (listing twenty nations with highest solar cooking potential, including India, China, and Brazil).

[203] *Id.*

[204] *See* Johnson et al., *supra* note 199, at 2456; *see also* JP Morgan, *supra* note 188.

[205] In 2002 3.5 million people died as a result of water-related diseases, making waterborne diseases a leading health concern. A. PRÜSS-ÜSTÜN ET AL., WORLD HEALTH ORG., SAFER WATER, BETTER HEALTH: COSTS, BENEFITS AND SUSTAINABILITY OF INTERVENTIONS TO PROTECT AND PROMOTE HEALTH 12 (2008), *available at* http://www.who.int/water_sanitation_health/publications/safer_water/en/; Annette Pruss et al., *Estimating the Burden of Disease from Water, Sanitation, and Hygiene at a Global Level*, 110 ENVTL. HEALTH PERSP. 537 (2002).

pollutants and their associated health risks, including chronic lung and heart disease. These negatively affect those who cook (generally women) and those they look after (young children and older people). Efficient cook stoves also reduce weight when women must carry fuel on their heads (head-loading). Head-loading causes prolapsed uterus, which causes increases in maternal mortality and stillbirths.[206] Finally, women and girls in refugee camps and areas of conflict and violence are physically vulnerable in their search for fuel. Efficient stoves increase well-being by diminishing these exposures as well.[207]

Transformational change is also possible in the forestry and agriculture sectors. As we discussed in Part I, it will be difficult, if not impossible, to achieve global per capita emissions of two tons per person without major reductions in emissions from these sectors. Fortunately, recent experimentation in each sector suggests that it is possible for changes in these sectors to contribute substantially to decreases in climate impact and increases in well-being.

For example, the Green Belt Movement BioCarbon Project is a large scale reforestation enterprise that consists of small community-based reforestation projects.[208] Communities secure a long-term license for the use of all non-wood forest products with the possibility of renewal. Communities ("Forest User Groups") give the Green Belt Movement the CDM rights in exchange for tree planting support, land rents, payments for surviving trees, and a share of the carbon revenues. The Green Belt Movement sells those rights to pay for the activities, and the World Bank finances the enterprise by securitizing the future carbon revenues from the CDM market.[209]

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[206] Ctr. for Sci. & Env't, CSE Draft Dossier on Health and Environment: Vulnerable Groups 15–20 (draft for conference, Mar. 24-25, 2006), *available at* http://www.cseindia.org/programme/health/pdf/conf2006/b1women.pdf.

[207] *See* Mieko Nishimizu, Energy, Health, and Gender — Thinking Differently About What We Do, Keynote Speech at the Regional Workshop on Household Energy, Indoor Health Pollution and Health, New Delhi, India (May 9, 2002), *available at* http://www.cleanairnet.org/caiasia/1412/articles-35922_recurso_1.pdf (discussing a range of health and environmental hazards of development including head-loading); Jerome Nriagu et al., *Environmental Risks and Disease Burdens in Developing Countries, in* ENVIRONMENTAL HEALTH: FROM GLOBAL TO LOCAL 310 (Howard Frumkin ed., 2005).

[208] *See, e.g.*, Green Belt Movement, Green Belt Movement/World Bank Biocarbon Project. Description of Green Belt Movement's Carbon Credit Project (2006), *available at* http://www.greenbeltmovement.org/a.php?id=197 (providing description of the project). For descriptions of similar projects, see The Equilibrium Fund, Reforestation, Food Forests and Carbon Offsets (2007), *available at* http://www.theequilibriumfund.org/page.cfm?pageid=5494; JOSHI GOPA, THE CHIPKO MOVEMENT AND WOMEN (Sept. ed. 1982), *available at* http://www.pucl.org/from-archives/Gender/chipko.htm. For other programs and models, see LORENA AGUILAR ET AL., REFORESTATION, AFFORESTATION, DEFORESTATION, CLIMATE CHANGE AND GENDER (2007); Boyd, *supra* note 125, at 4–9.

[209] *See* Press Release, World Bank, World Bank & Greenbelt Movement Project to Reforest Regions of Kenya (Nov. 15, 2006), *available at* http://www.worldbank.org/WBSITE/EXTERNAL/NEWS/0,,contentMDK:21133046~pagePK:34370~piPK:34424~theSitePK:4607,00.html; FREDERICK NAJAU & IRENE MUTHUKA, KENYA GREEN BELT MOVEMENT REFORESTATION PROJECT BIOCF PROJECT (2008), *available at* http://www.whrc.org/Africa/assets/NjauandMuthuka-GBM%20Reforestation%20CDM%20Project.pdf.

Many opportunities also exist for transformative change in the agriculture sector. We focus here on the energy use associated with fertilizer for two reasons. First, fertilizer production is a very energy-intensive part of the agricultural process.[210] Second, claims about the fertilizer-dependent green revolution model of agriculture and its productivity are a potential reason why the climate impact of the agricultural sector cannot be addressed if world food needs are to be met.

A review of the literature prepared by the Food and Agriculture Organization of the United Nations shows that organic agriculture[211] can increase productivity, decrease the need for inputs (including fertilizer and irrigation), increase resilience in the face of environmental stresses (e.g., drought, floods) and local pests and diseases, increase food security and income security through multi-cropping, and decrease food dependency on imports.[212] Moreover, organic sustainable agriculture could meet growing global demand.[213] Fortunately, this form of agriculture also can increase the well-being of farmers and consumers.[214] Health and nutrition benefits for consumers can arise from the variety of locally grown fruits and vegetables that are often grown organically. Benefits can arise for farmers from the lack of exposure to pesticides, herbicides, and fertilizers that are spread by hand in much of the developing world.

These initiatives in households, forestry, and agriculture are examples of locally appropriate strategies for improving well-being while decreasing GHG emissions. They have been successful and deployed in multiple con-

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[210] Jason McKenney, *Artificial Fertility: The Environmental Costs of Industrial Fertilizers*, *in* FATAL HARVEST: THE TRAGEDY OF INDUSTRIAL AGRICULTURE 239 (Andrew Kimbrell ed., 2002) ("The production of nitrogenous fertilizers consumes more energy than any other aspect of the agricultural process."). In addition, as Tilman et al. anticipate,

> Should past dependences of the global environmental impacts of agriculture on human population and consumption continue, 109 hectares of natural ecosystems would be converted to agriculture by 2050. This would be accompanied by 2.4- to 2.7-fold increases in nitrogen- and phosphorus-driven eutrophication of terrestrial, freshwater, and near-shore marine ecosystems, and comparable increases in pesticide use. This eutrophication and habitat destruction would cause unprecedented ecosystem simplification, loss of ecosystem services, and species extinctions.

David Tilman et al., *Forecasting Agriculturally Driven Global Environmental Change*, 292 SCIENCE 281, 281 (2001).

[211] For examples of organic and integrated agriculture, see descriptions of projects in Vietnam, Heifer International, http://www.heifer.org/site/c.edJRKQNiFiG/b.201470/ (last visited Apr. 26, 2009) (on file with the Harvard Environmental Law Review); in India, Navdanya, http://www.navdanya.org/ (last visited Apr. 26, 2009) (on file with the Harvard Environmental Law Review).

[212] Nadia El-Hage Scialabba, Conference on Organic Agriculture and Food Security, Oslo, Norway, *Can Africa Feed Itself? Organic Agriculture and Food Security in Africa* 5 (June 6-8, 2007).

[213] *See id.* (concluding that "[r]ecent models of a hypothetical global food supply grown organically indicates that organic agriculture could produce enough food on a global *per capita* basis for the current world population: 2640 and 4380 kcal/person/day, depending on the model used" (citations omitted) (emphasis in original)).

[214] For example, benefits may arise from increased consumption of fruits and vegetables and reduced exposure of farmers to pesticides.

texts. They exhibit the core characteristics of a new path for climate justice policy discussions.

Of course, many questions remain about such initiatives, including how each might be scaled up or replicated in general and in any particular setting. Our purpose is not to answer these questions, but to reorient the climate change-global justice scholarship and policy dialogue so that more of us are asking these questions and developing policy-relevant proposals.

III. Conclusion

Climate change and global justice are difficult to address together, but it is unlikely that either will be resolved if they are treated as separate issues. We should not allow opaque, optimistic assumptions to obscure the choice we are making to forgo even a reasonable aspiration of achieving the widely adopted 2°C target. Instead, we should confront the hard questions that arise when we try to develop policy architectures and initiatives that enable us to achieve that target. When we do so, we will be forced to confront the essential relationship between climate change and global justice, and we will be forced to add a new, transformative set of approaches to the current proposed policy architectures. We have proposed several core characteristics of the new policy architectures, as well as examples of near-term and long-term initiatives.

As we indicated at the outset, it is possible that climate sensitivity will turn out to be less than currently projected, that revolutionary development and adoption of technology will occur, that markets and policy implementation will function perfectly, that per capita incomes will increase without inducing GHG emissions that exceed emissions targets, and that the other optimistic assumptions of proposed policy architectures will turn out to be sound. Many, if not all, of these assumptions need to be sound to substantially reduce the risk of catastrophic climate change, however. There is little margin for error, and the accumulation of optimistic assumptions raises serious concerns about the plausibility of the current policy architectures. We suggest that it is only prudent to be transparent about these assumptions so that conscious choices can be made about whether more fundamental — and more difficult — steps are worth taking. If we fail to confront the hard questions, we will not even have the opportunity to make the hard choices.