CHAPTER 9

Beyond business as usual: alternative wedges to avoid catastrophic climate change and create sustainable societies

Philip Cafaro

There is a curious disconnect in climate change discourse, between explanations of the causes of global climate change (GCC) and discussions of possible solutions. On the one hand, it is widely acknowledged that the primary causes of climate change are unremitting economic and demographic growth. As the fourth assessment report from the Intergovernmental Panel on Climate Change (IPCC) succinctly puts it: "GDP/per capita and population growth were the main drivers of the increase in global emissions during the last three decades of the 20th century ... At the global scale, declining carbon and energy intensities have been unable to offset income effects and population growth and, consequently, carbon emissions have risen."[1] On the other hand, most proposals for climate change mitigation take growth for granted and focus on technical means of reducing greenhouse gas emissions.

Climate scientists speak of the "Kaya identity": the four primary factors which determine overall greenhouse gas emissions. They are economic growth/per capita, population, energy used to generate each unit of GDP, and greenhouse gases generated per unit of energy. Over the past three and a half decades, improvements in energy and carbon efficiency have been overwhelmed by increases in population and wealth. Here are the numbers, again according to the IPCC: "The global average growth rate of CO_2 emissions between 1970 and 2004 of 1.9% per year is the result of the following annual growth rates:

population + 1.6%,
GDP/per capita + 1.8%,

[1] Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2007: Mitigation* (2007), Technical Summary, p. 107.

energy-intensity (total primary energy supply (TPES) per unit of GDP) – 1.2%, and carbon-intensity (CO_2 emissions per unit of TPES) – 0.2%."[2]

Crucially, the IPCC's projections for the next several decades see a continuation of these trends (Figure 1). More people living more affluently mean that under "business as usual," despite expected technical efficiency improvements, greenhouse gas emissions will increase between 25 and 90 percent by 2030, relative to 2000 (note the net change increases projected in Figure 1).[3] If we allow this to occur, it will almost surely lock in global temperature increases of more than 2°C over pre-industrial levels, exceeding the threshold beyond which scientists speak of potentially catastrophic climate change. Following this path would represent a moral catastrophe as well: the selfish over-appropriation and degradation of key environmental services by the current generation to the detriment of future ones, by rich people to the detriment of the poor, and by human beings to the great detriment of the rest of the living world.[4]

A reasonable person reading the IPCC report and subsequent scientific literature on climate change would likely conclude that we are bumping up against physical and ecological limits. Given the dangers of catastrophic GCC, a prudent and moral response might be: "Wow! This is going to be hard. We need to start working on this problem with all the tools at our disposal. Increasing energy and carbon efficiency, to be sure. But also decreasing the pursuit of affluence and overall consumption; and stabilizing or reducing human populations. Maybe in the future we can grow like gangbusters again, maybe not. But for now, people need to make fewer demands on nature and see if even our current numbers are sustainable over the long haul. After all, our situation is unprecedented – 6.9 billion people living or aspiring to live in modern, industrialized economies – and there is no guarantee that we aren't already in 'overshoot' mode."

Such convictions would only be strengthened by considering further evidence of global ecological degradation from the recent *Millennium Ecosystem Assessment* (MEA), including the depletion of important ocean fisheries, accelerating soil erosion, ongoing species extinctions throughout the world, the growth of immense "dead zones" at the mouths of many great rivers, and more. According to the MEA, humanity is currently degrading or utilizing unsustainably fifteen of twenty-four key ecosystem services.[5]

[2] Ibid. [3] Ibid., p. 111.

[4] Donald Brown *et al.*, *White Paper on the Ethical Dimensions of Climate Change*, Rock Ethics Institute, Pennsylvania State University (2007).

[5] Walter Reid *et al.*, *The Millennium Ecosystem Assessment: Ecosystems and Human Well-Being: Synthesis* (Washington, DC: Island Press, 2005).

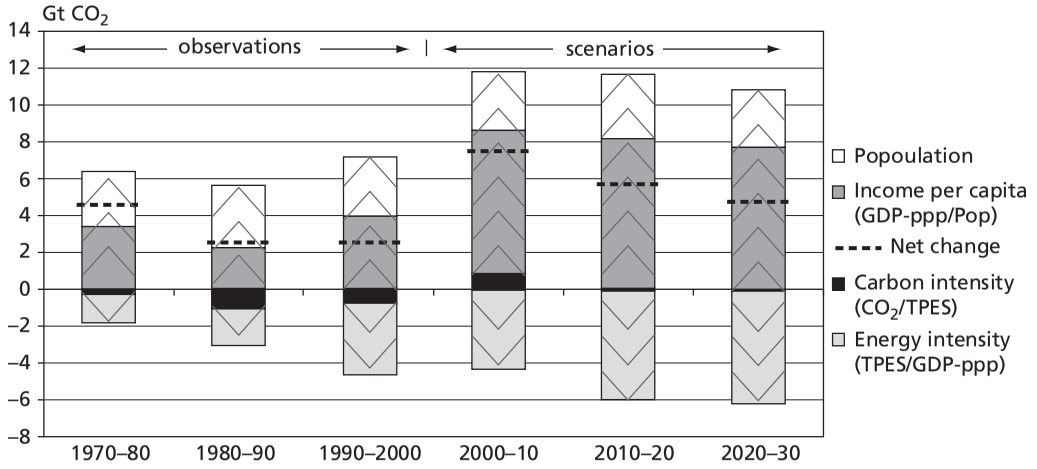


Figure 1 Decomposition of global energy-related CO_2 emission changes at the global scale for three past and three future decades. Source: IPCC, *Climate Change 2007: Mitigation*, Technical Summary, figure 1.6. GDP-ppp/Pop = gross domestic product per person/total population; CO_2/TPES = total CO_2 emissions/total primary energy supply; TPES/GDP-ppp = total primary energy supply/gross domestic product per person.

However, neither GCC nor any of these other problems have led to a widespread re-evaluation of the goodness of growth.[6] Regarding GCC, we have seen a near-total focus on technological solutions by politicians, scientists, and even environmentalists. I contend that this is a serious mistake. Because business as usual with respect to growth probably cannot avoid catastrophic GCC or meet our other global ecological challenges, we need to consider a broader range of alternatives that include slowing or ending growth. Philosophers exploring this issue should ask what ethical role the notion of growth plays within climate change debates, and how widely held views of the sanctity of growth may close off viable or preferable courses of action. Continued neglect of this topic will undermine philosophers' attempts to specify a just and prudent course of action on climate change.

1 THE WEDGE APPROACH

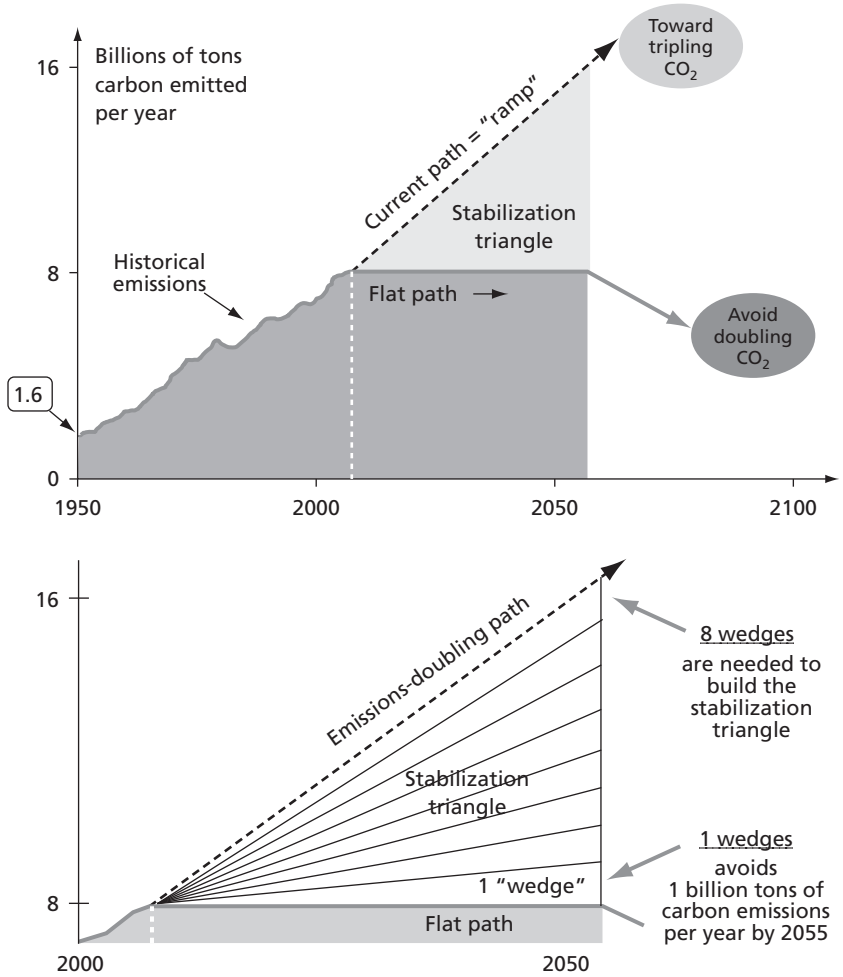
Of the many possible examples of mainstream approaches to climate change mitigation that we might consider, let us look at one of the most rigorous and influential, Stephen Pacala and Robert H. Socolow's "wedge" approach.[7] The wedge approach is a heuristic designed to help us compare alternative mitigation schemes. Pacala and Socolow's stated goal, in the face of numerous mitigation proposals and skepticism about whether any of them can succeed, is to provide a practical road map of choices that can facilitate successfully addressing the problem of GCC.

Each wedge in the "stabilization triangle" (Figures 2a and 2b) represents a technological change which, fully implemented, would keep 1 billion metric tons of carbon from being pumped into the air annually, 50 years from now. It would also prevent 25 billion metric tons of carbon from being released during the intervening 50 years.[8] The authors figure that eight such wedges must be implemented – not to reduce atmospheric CO_2; not to stabilize

[6] Brian Czech, *Shoveling Fuel for a Runaway Train: Errant Economists, Shameful Spenders, and a Plan to Stop them All* (Berkeley, CA: University of California Press, 2002); Gustave Speth, *The Bridge at the Edge of the World: Capitalism, the Environment, and Crossing from Crisis to Sustainability* (New Haven, CT: Yale University Press, 2009).

[7] This approach was first presented in Stephen Pacala and Robert Socolow, "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies," *Science*, 305 (2004), pp. 968–972. The latest iteration is Robert H. Socolow and Mary English, "Living Ethically in a Greenhouse," Chapter 8 in this volume. Recent research and even a downloadable version of the "Carbon Mitigation Wedge Game" can be found at the website for the Carbon Mitigation Initiative (www.princeton.edu/~cmi).

[8] In the most recent version of this approach, each wedge prevents 4 billion metric tons of CO_2 from being emitted annually, rather than 1 billion metric tons of carbon. Since 1 metric ton of carbon equals 3.67 metric tons of CO_2, the wedges are slightly larger in the new version.



Figures 2a and 2b Stabilization Triangles.
Source: Carbon Mitigation Initiative, Princeton University.

CO_2 levels – but simply to keep atmospheric carbon from doubling and pushing past potentially catastrophic levels during this period. In order to fully address GCC, in the following 50 years, humanity would have to take further steps and move to an economy where human carbon outputs do not exceed carbon uptakes in natural systems. The wedge approach buys us time and (allegedly) begins the transition toward such an economy. Table 1 shows the fifteen carbon reduction wedges proposed by Pacala and Socolow.

Table 1 *Potential conventional carbon mitigation wedges*

	Option	Effort by 2054 for one wedge, relative to 14 gigatons of carbon per year (GtC/year) under business as usual
Energy efficiency and conservation	1. Efficient vehicles	Increase fuel economy for 2 billion cars from 30 to 60 mpg (12.75 to 25.5 km/l)
	2. Reduced vehicle use	Decrease car travel for 2 billion 30-mpg (12.75 km/l) cars from 10,000 to 5,000 miles (16,100 to 8,050 km) per year
	3. Efficient buildings and appliances	Cut carbon emissions by 1/4 in projected buildings and appliances
	4. Efficient baseload coal plants	Produce twice today's coal power output at 60% efficiency compared with 32% efficiency today
Fuel shift	5. Gas baseload power for coal baseload power	Replace 1,400 GW coal plants with natural gas plants (4 times current gas-based power production)
	6. Nuclear power for coal power	Add 700 GW nuclear power (tripling current capacity)
Carbon capture and storage	7. Capture CO_2 at power plants	Introduce CCS at 800 GW coal plants or 1,600 GW natural gas plants
	8. Capture CO_2 at hydrogen (H_2) plant	Introduce CCS at plants producing 250 million metric tons H_2/year from coal or 500 million metric tons H_2/year from natural gas
	9. Capture CO_2 at coal-to-synfuel plant	Introduce CCS at synfuel plants producing 30 million barrels per day from coal (200 times current capacity)
Renewable electricity and fuels	10. Wind power for coal power	Add 2 million 1-MW-peak windmills (50 times current capacity) occupying 30 million hectares, on land or offshore
	11. Photovoltaic (PV) power for coal power	Add 2,000 GW-peak PV (700 times current capacity) on 2 million hectares
	12. Wind-generated H_2 fuel-cell cars for gasoline-powered cars	Add 4 million 1-MW-peak windmills (100 times current capacity)
	13. Biomass fuel for fossil fuel	Add 100 times current Brazil or US ethanol production, with the use of 250 million hectares (1/6 of world cropland)
Forests and agricultural soils	14. Reduce deforest-ation, plus reforestation and new plantations	Halt tropical Deforestation instead of 0.5 billion metric tons C/year loss, and establish 300 million hectares of new tree plantations (twice the current rate)
	15. Conservation tillage	Apply best practices to all world cropland (10 times the current usage)

Source: Carbon Mitigation Initiative, Princeton University (table modified).

Despite a stated desire to consider only alternatives that are technically feasible today, scaling up the carbon capture and storage options (wedges 7–9) appears to rely on future technological improvements that may not prove practicable.[9] While some of the wedges could pay for themselves over time, most, on balance, would involve significant economic costs. Most wedges also carry significant environmental costs, which in some cases may equal or outweigh the environmental benefits they would provide in helping mitigate GCC. This is arguably the case with the proposed nuclear wedge, given problems with waste disposal. Similarly, the coal wedges would encourage continued environmental degradation from coal mining. Even seemingly benign alternatives, such as wind or solar power expansion, will result in huge wildlife habitat losses if pursued on the scale demanded to achieve a full wedge.

One strength of the wedge approach is that it allows us to specify the costs and benefits of different courses of action and thus choose intelligently between them. So far this has mostly meant asking which wedges are cheapest economically. But the approach also allows us to compare alternatives based on environmental impacts, equitable sharing of costs and benefits, overall contribution to sustainability, or whatever criteria we deem relevant – if, that is, we are considering a reasonably complete set of alternatives.

Take another look at the fifteen proposed wedges. Fourteen focus on improvements in energy efficiency, or substitutions in energy and materials production; one or perhaps two wedges involve limiting consumption (cutting the miles driven by automobile drivers; maybe limiting deforestation); and none of them involve limiting human population growth. This is hardly a peculiarity of Pacala and Socolow. Most discussions of GCC neglect the possibility of limiting consumption or stabilizing populations. The goal, always, seems to be to accommodate *more* consumption by *more* people with *less* environmental impact.

Numerous illustrations can be cited from the IPCC's fourth assessment report itself. Its authors recognize agriculture as a major contributor to GCC, for example. Yet they simply accept projections for greatly increased demands for all categories of agricultural products (including a doubling in worldwide demand for meat over the next fifty years) and focus on changes in tillage, fertilizer use, and the like, as means to limit increased greenhouse

[9] Synapse Energy Economics, *Don't Get Burned: The Risks of Investing in New Coal-Fired Generating Facilities* (New York: Interfaith Center on Corporate Responsibility, 2008), pp. 29–30.

gas emissions.[10] Similarly, the assessment report notes that among significant greenhouse gas sources, aviation traffic is the fastest-growing sector worldwide. It considers numerous changes to aviation practices, including relatively trivial improvements in airplane technology and changes in worldwide flight patterns, while avoiding the obvious alternative of reducing the number of flights.[11] Many similar examples could be given.

2 CAUSES AND CONSEQUENCES OF THIS FAILURE

Now we need to be clear. The failure to consider policies designed to reduce consumption or limit population can't be chalked up to these factors' unimportance. The IPCC assures us that they are all-important in generating GCC. Nor is it because there aren't policies that might reduce consumption or slow population growth; there are many policy alternatives in these areas. Nor is it because such policies necessarily would be more expensive, harder to implement, more coercive, or in any other way less appealing than the technological approaches under consideration. Some may be, of course. But as I show below, there are almost certainly consumption and population wedges that could be developed and implemented at less economic, environmental, and social cost than most of the wedges proposed by Pacala and Socolow, and even with considerable overall benefit.

The real problem, I submit, is that the majority of policymakers and analysts are so ideologically committed to maximizing growth that it is impossible for them to consider the full range of alternatives. There are legitimate pragmatic worries that questioning growth will turn the public against climate change mitigation, and legitimate questions about how to reduce growth without reducing people's quality of life. Still, this failure could prove disastrous. Dire as the predictions in the fourth assessment report were, the scientific literature has grown even grimmer in the years since its publication, leading some climate scientists to argue that humanity must reduce greenhouse gas emissions more quickly and stabilize emissions at lower levels than previously thought.[12] We may not need eight wedges over the next fifty years, but ten or more, to avoid catastrophic GCC. Furthermore, like other approaches focused on midterm carbon reductions, the wedge framework

[10] IPCC, *Climate Change 2007: Mitigation*, ch. 8, "Agriculture".

[11] Ibid., ch. 5, "Transport and Its Infrastructure"; see also IPCC, *Aviation and the Global Atmosphere* (1999).

[12] James Hansen, "Scientific Reticence and Sea Level Rise," *Environmental Research Letters*, 2 (2) (2007), article 024002; James Hansen *et al.*, "Target Atmospheric CO_2: Where Should Humanity Aim?," *Open Atmospheric Science Journal*, 2 (2008), pp. 217–231.

postulates a transition to *much* lower emissions in the long term, in order to meet the GCC challenge. But such a transition seems unlikely if we squeeze all the most easily achieved efficiency gains out the system, while increasing the number of people and ratcheting up their per capita demands.

Pacala and Socolow try to meet this problem by advocating increased research and putting their faith in future technological breakthroughs to achieve a near-zero carbon society. I believe we cannot rest in such faith, given the stakes involved. I'm all for increased research into new energy technologies. But I think we'll probably need wisdom as well as cleverness, self-restraint as well as technological ingenuity, to avoid catastrophic GCC. And as many of the contributors to this volume argue, meeting this challenge is a moral imperative. Morality demands that this generation of wealthy human beings construct a plausible bridge to a sustainable future, and walk across it. It also demands that this bridge be one that the world's poor and other species can cross along with us.[13]

Proposals to trade in our old air-conditioned SUVs for new, air-conditioned *hybrid* SUVs and roar into the future with the hope of a Hail Mary techno-pass at the end do not meet our moral obligations.[14] This is so, because the potential harms are so great. The fourth assessment report speaks of the likelihood that, during the coming decades, tens and perhaps hundreds of millions of poor people will have their lives threatened by GCC-induced droughts and famines, storms, and floods.[15] It estimates that 20 to 30 percent of the world's species will be extinguished or threatened with extinction by the end of the century, under business as usual emissions scenarios.[16] Such immense harms, should they occur, will have been caused (at least partly) by us, and they can be averted (at least partly) by us. The

[13] Brown *et al.*, *Ethical Dimensions of Climate Change*; Holmes Rolston III, "Duties to Endangered Species," in Rolston, *Philosophy Gone Wild: Environmental Ethics* (Buffalo, NY: Prometheus Books, 1989), pp. 206–219.

[14] Nor do radical geoengineering schemes to mitigate GCC. Stephen Gardiner details several such proposals and suggests that their proliferation exemplifies a "moral corruption" that seeks to avoid full responsibility for dealing with the problem ("Is 'Arming the Future' with Geoengineering Really the Lesser Evil? Some Doubts about the Ethics of Intentionally Manipulating the Climate System," in Gardiner, Simon Caney, Dale Jamieson and Henry Shue (eds.), *Climate Ethics: Essential Readings* (Oxford University Press, 2010). There are ample anthropocentric reasons for opposing climate geoengineering, based on its uncertain impacts on future human generations; I am also impressed by its breathtaking anthropocentrism. In effect, such proposals accept that the Earth, which over eons has been home to an amazing and ever-increasing diversity of hundreds of millions of species, will henceforth be managed for the benefit of one species: *Homo sapiens sapiens*. I call this interspecies genocide. But GCC policy should not be about securing *Lebensraum* for the master species.

[15] IPCC, *Climate Change 2007: Synthesis Report*, pp. 48–52.

[16] Ibid., p. 48. See also Chris Thomas *et al.*, "Extinction Risk from Climate Change," *Nature*, 427 (2004), pp. 145–148; *Millennium Ecosystem Assessment*, Biodiversity Synthesis, pp. 42–47.

scale of these potential harms and our responsibility for causing them demand a commensurate response, one with a *high likelihood* of averting catastrophic GCC, not just the *possibility* of doing so.

"Can Advances in Science and Technology Prevent Global Warming?" asks Michael Huesemann in a recent review article of the same name. After detailed analysis, he answers that an exclusive focus on efficiency improvements is unlikely to prevent catastrophic GCC. Indeed, "it is highly questionable that 12-fold to 26-fold increases in Gross World Product [over the twenty-first century, as predicted by the IPCC] are even remotely achievable because of biophysical constraints and the inability of technology to sufficiently uncouple energy and materials use from the economy."[17] Meeting the GCC challenge almost certainly depends on ending human population growth and either ending economic growth or radically transforming it, so that *some* economic growth in *some* sectors of the modern economy and in poorer countries that can actually benefit from it can be accommodated without radically destabilizing the Earth's climate. All the technological improvements we can muster will probably be necessary to enable this transition to a slow-growth or post-growth future – not as an alternative to it.[18]

Given the stakes involved, we should consider our full range of options. In the remainder of this chapter, I propose a number of alternative wedges focused on reductions in consumption, population growth, and economic growth. If techno-wedges are sufficient or superior, then they should be able to demonstrate that in a direct comparison with these alternative wedges. If not, then they should be supplemented or supplanted by the alternatives.

3 ALTERNATIVE WEDGES: CONSUMPTION

Consider four consumption wedges, the first two focused on food consumption and transportation, and the following two seeking to rein in consumption more generally. Once again, each of these wedges represents a technological or policy change that would prevent 1 billion metric tons of carbon from being emitted 50 years from now and 25 billion metric tons from being emitted over the next 50 years.[19]

[17] Michael Huesemann, "Can Advances in Science and Technology Prevent Global Warming? A Critical Review of Limitations and Challenges," *Mitigation and Adaptation Strategies for Global Change*, 11 (2006), p. 566.

[18] Bill McKibben, *Deep Economy: The Wealth of Communities and the Durable Future* (New York: Henry Holt, 2007).

[19] See the page "Alternative Climate Wedges" on my website (www.philipcafaro.com) for more detailed specifications and supplementary material on these and other wedges described in the following sections.

3.1 Meat wedge

According to a recent comprehensive study, agriculture currently contributes 18 percent of total world greenhouse gas emissions and livestock production accounts for nearly 80 percent of this.[20] Thus meat-eating contributes approximately 2.38 billion metric tons carbon equivalent to current greenhouse gas emissions. The UN Food and Agricultural Organization projects a worldwide doubling in animal production between 2000 and 2050, from 60 billion to 120 billion animals raised annually, which, under "business as usual," will double the greenhouse gas emissions from this sector to 4.76 billion metric tons. If, instead, we hold worldwide animal food production steady over the next 50 years, this would provide nearly two and a half carbon wedges (averting a 2.38 billion metric tons increase), while merely preventing half the projected doubling during that time would supply more than one full carbon wedge (1.19 billion metric tons averted).[21] Such wedges might be accomplished non-coercively by increasing the price of meat, removing subsidies for cattle production, banning confined animal feedlot operations (CAFOs) as the European Union is in the process of doing, and directly taxing meat to discourage consumption. These measures could accommodate a reasonable increase in meat-eating in poor countries where many people eat little meat, while providing environmental and health benefits in wealthy countries where people eat more meat than is good for them.[22] They could complement efforts to improve the conditions under which food animals are raised, changes that may be expensive, but which are arguably demanded by morality anyway.[23]

3.2 Aircraft wedge

According to the fourth assessment report, civil aviation is one of the world's fastest-growing sectors of significant greenhouse gas emissions. Analysis shows that air traffic "is currently growing at 5.9% per year [and] forecasts predict a global average annual passenger traffic growth of around

[20] United Nations Food and Agriculture Organization, *Livestock's Long Shadow: Environmental Issues and Options* (Rome: 2006), p. 112.

[21] Gidon Eshel and Pamela Martin, "Diet, Energy, and Global Warming," *Earth Interactions*, 10 (2006), paper no. 9.

[22] Philip Cafaro, Richard Primack, and Robert Zimdahl, "The Fat of the Land: Linking American Food Overconsumption, Obesity, and Biodiversity Loss," *Journal of Agricultural and Environmental Ethics*, 19 (2006), pp. 541–561.

[23] Bernard Rollin, *Animal Rights and Human Morality*, 3rd ed. (Buffalo, NY: Prometheus Books, 2006). For a detailed discussion of the meat/heat connection, see the report *Global Warning: Climate Change and Farm Animal Welfare* from the group Compassion in World Farming (Godalming, UK: 2007).

5% – passenger traffic doubling in 15 years."[24] Under current projections, carbon emissions from aircraft might increase from 0.2 billion metric tons per year to 1.2 billion metric tons annually over the next 50 years.[25] In addition to emitting CO_2, airplanes increase "radiative forcing" through emissions of other greenhouse gases and by creating contrails and cirrus clouds, thus changing atmospheric conditions. Although the science remains uncertain, it appears that these contributions to global warming may be "2 to 4 times larger than the forcing by aircraft carbon dioxide alone."[26] Let's assume, conservatively, that the other effects of aviation add up to twice the impact of CO_2 emissions. Preventing half this increase would give us half a wedge from carbon alone (0.5 billion metric tons less carbon emissions annually, 50 years from now) and one and a half wedges overall, while holding total flights at current levels would supply a full wedge from carbon and three wedges overall. Once again, such reductions could be achieved by increasing the cost of air travel by taxing it. Such a proposal was recently put before the parliament of the European Union.[27] Alternatively, countries might decide that GCC is important enough to demand sacrifices from all their citizens, even rich ones, and strictly limit the number of allowable discretionary flights per person. The USA rationed gasoline use during World War II; perhaps GCC demands an equally strenuous and across-the-board response.

The fourth assessment report does not consider such demand-reduction alternatives, nor do most governments or policy analysts. But they should. A recent study titled "International Aviation Emissions to 2025: Can Emissions Be Stabilized Without Restricting Demand?" answered with a resounding "no." With efficiency improving three times slower than the rate of increased demand and with no transformative technologies on the horizon, the air transport sector cannot make a sufficient contribution to mitigating GCC without limiting demand for air travel.[28] Meanwhile total emissions may need to decrease by 60–80 percent in the next fifty years in order to avert catastrophic GCC. Clearly this cannot happen while major economic sectors *increase* their emissions.

[24] IPCC, *Climate Change 2007: Mitigation*, p. 334.
[25] IPCC, *Aviation and the Global Atmosphere*.
[26] Ibid., "Summary for Policymakers," section 4.8.
[27] Commission of the European Communities, "Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC so as to include aviation activities in the scheme for greenhouse gas trading within the community" (Brussels), COM (2006) 818 final, 2006/0304 (COD).
[28] Andrew Macintosh and Lailey Wallace, "International Aviation Emissions to 2025: Can Emissions Be Stabilized Without Restricting Demand?" *Energy Policy*, 37 (2009), pp. 264–273.

3.3 Carbon tax wedges

A general carbon tax is by common consent one of the most economically efficient ways to cut carbon emissions. While such taxes are usually presented as means to force technological innovation and decrease pollution per unit of consumption, they also incentivize less consumption, and part of the success of a carbon tax in lowering emissions undoubtedly would come from getting people to consume less. According to the IPCC, a tax of $50 per metric ton of carbon dioxide equivalent could prevent from 3.5 to 7 billion metric tons of carbon equivalent from being emitted annually by 2030, while a tax of $100 per metric ton of carbon dioxide equivalent could prevent from 4.3 to 8.4 billion metric tons carbon equivalent from being emitted annually.[29] Projected out to 2060, such taxes could provide from 5.6 to 13.4 wedges of carbon reduction.[30] In other words, a right-sized carbon tax, by itself, could conceivably provide the 8 or more wedges needed to avoid catastrophic GCC.

A carbon tax is so effective because it affects consumption across the board, from airplane travel to new home construction to food purchases. It treats all these areas equally, from an emissions perspective, and does not distinguish between frivolous and important, useful or useless consumption. That is both its (economic) strength and its (ethical) weakness, and why it should probably be supplemented by measures that directly target unnecessary carbon emissions.

3.4 Luxury wedges

Like any general consumption tax, a carbon tax is regressive, hitting the poor harder than the rich. However, there is a case to be made that in a greenhouse world, everyone should do their part, including the wealthy, by limiting unnecessary consumption. Consider again airplane travel, where we saw that holding the number of flights steady over the next fifty years might provide three wedges. If we assume that the wealthiest 10 percent of the world's population (roughly those with an annual income of $10,000 or

[29] IPCC, *Climate Change 2007: Mitigation*, "Summary for Policymakers," pp. 9–10, tables SPM-1 and SPM-2.

[30] Note that these taxes would scale up in from two to two and a half decades, rather than the five decades in Pacala and Socolow's original wedges. I have (arbitrarily) assumed that the taxes would provide the same amount of annual carbon reductions in succeeding years. Strictly speaking, the resulting figure is not a triangular carbon "wedge" but a carbon trapezoid. A similar point applies to the economic growth reduction wedges discussed in a later section.

more)[31] account for 90 percent of flights and that much of this travel is discretionary, then we might construct our plane wedges in a way that transformed them, to some degree, into luxury wedges. For example, we might tax a person's first flight at a percentage n of the cost of a ticket, her second at $n \times 2$, her third at $n \times 3$, and not allow more than p personal flights annually (with medical or bereavement exceptions) – and ban the personal ownership and use of planes (again allowing for reasonable exceptions in the public interest). In a similar manner, Pacala and Socolow's "reduced vehicle use" and "efficient buildings" wedges might be partially transformed into luxury wedges, through some combination of progressive taxation and outright prohibitions. Automobiles priced above n that did not meet fuel efficiency standards could be taxed at a percentage q of the cost of the vehicle, at $2 \times q$ of the cost for even less efficient vehicles, etc. – while the least efficient vehicles could be banned (with exceptions for work-related vehicles and transportation for the handicapped). Houses with floor plans larger than n square meters could be taxed at a percentage r for the first extra thousand square meters, $2 \times r$ for the next thousand, and $3 \times r$ for the third extra thousand – while even larger houses could be prohibited (again, with reasonable exceptions).

While suggestions to prohibit unnecessary, high-emission consumption tend to be unpopular, I think they have considerable merit. It is possible to construct luxury wedges without prohibitions, solely through progressive taxation; and an "efficiency" case can be made that the extra tax revenues generated by luxury consumption justify allowing it to continue, particularly if those revenues are used to mitigate GCC or benefit the poor. On the other hand, setting strict limits to individual carbon pollution would acknowledge the seriousness of the problem and represent a society-wide commitment to avoiding catastrophic GCC. Theoretically, efficient approaches which undermine such moral commitment – by encouraging the wealthy to burnish their status through luxury consumption, while the common folk ape or envy them – might wind up being ineffective, and hence not truly efficient.

It has become a commonplace in ethical discussions of GCC to say that we should not try to solve this problem on the backs of the poor. As Henry Shue puts it in his article "Subsistence Emissions and Luxury Emissions,"

[31] In 1993, the annual per capita income of people in the 90th percentile of income distribution worldwide was $9,110, according to Branko Milanovic, "True World Income Distribution, 1988 and 1993: First Calculations, Based on Household Surveys Alone," World Bank, Development Research Group, policy research working paper 2244 (November 1999), p. 30, table 19.

"the central point about equity is that it is not equitable to ask some people to surrender necessities so that other people can retain luxuries."[32] But it is probably also true that we won't be able to solve the problem solely on the backs of the world's striving middle classes, who are unlikely to forego desired consumption or pay much more for goods and services, without strong evidence that the wealthy are also doing their fair share – and not just buying their way out of doing so. Arguably, from a fairness perspective, from a wide buy-in perspective, and from a maximal emissions reductions perspective, it makes sense to consider the absolute prohibition of some high-energy, luxury consumption.[33]

Happily, we do have some possibilities for decreasing emissions by increasing people's consumption options; for example, building high-speed trains in Japan and Western Europe has apparently helped slow growth in domestic and regional plane travel, lowering overall carbon emissions. We need to push such win/win strategies (see the next section), while remaining realistic about how much they can achieve. Improved technologies and more options, by themselves, likely cannot achieve sufficient emissions reductions. We probably will need a mix of "goodies" (incentives and increased options) and "baddies" (general carbon taxes, luxury consumption taxes, and outright prohibitions) to find the most efficient and fair means to cut consumption and rein in GCC.

4 ALTERNATIVE WEDGES: POPULATION

When we turn to potential population wedges, we need to remember that population growth is one of the two main drivers of GCC.[34] Again according to the IPCC's fourth assessment report, "The effect on global emissions of the decrease in global energy intensity (–33%) during 1970 to 2004 has been smaller than the combined effect of global per capita income growth (+77%) and global population growth (+69%); both drivers of increasing

[32] Henry Shue, "Subsistence Emissions and Luxury Emissions," *Law and Policy*, 15 (1993), p. 56.

[33] Surprisingly, I have not found any discussion in the scientific or philosophical literatures of what role cutting back on high-end consumption might play in a comprehensive effort to mitigate GCC; hence my discussion of luxury wedges is underdeveloped. However, it seems to me such alternatives should be considered as a matter of basic fairness, and I would welcome suggestions for how to specify particular luxury wedges more rigorously.

[34] Brian O'Neill, Landis MacKellar, and Wolfgang Lutz, *Population and Climate Change* (Cambridge University Press, 2005); Brian O'Neill, "Climate Change and Population Growth," in Laurie Mazur (ed.), *A Pivotal Moment: Population, Justice and the Environmental Challenge* (Washington, DC: Island Press, 2009), pp. 81–94.

Table 2 *World population projections*

Projection	Annual growth rate	2050 population	2060 population
Low	0.40%	7.4 billion	8.0 billion
Medium	0.77%	8.9 billion	9.6 billion
High	1.12%	10.6 billion	11.8 billion

Source: UN Department of Economic and Social Affairs, Population Division, "World Population to 2300," p. 4.

energy-related CO_2 emissions."[35] When it comes to GCC and other environmental problems, "size (of the human population) matters."[36]

The current global population is approximately 6.9 billion people. Table 2 shows recent 50-year United Nations population projections at low, medium and high rates of growth.[37]

The medium projection is presented as the "most likely" scenario, although all three projections are considered possible depending on a variety of factors, including public policy choices. Note that all three projections, even the highest, assume fertility decreases and lower annual growth rates than in recent decades, based in part on improving efforts to provide contraception and encourage family planning. If these efforts falter, birth rates may remain high and populations 50 years from now may balloon past 12 billion.

In 2000, world per capita greenhouse gas emissions were 1.84 metric tons carbon equivalent. Assuming this emissions rate, each 543 million people added to Earth's population adds another 1 billion metric tons of annual carbon emissions; conversely, preventing the existence of 543 million people 50 years from now provides a full carbon reduction wedge (543 million × 1.84 tons = 1 billion metric tons). If we follow the UN report and take 9.6 billion as our business as usual population scenario, then successfully holding world population growth to the lower figure of 8.0 billion would provide 2.95 global population wedges. Conversely, allowing the world's population to swell to the high projection of 11.8 billion (still within the realm of

[35] IPCC, *Climate Change 2007: Mitigation*, "Summary for Policymakers," p. 3.

[36] Lindsey Grant, *Too Many People: The Case for Reversing Growth* (Santa Ana, CA: Seven Locks Press, 2001).

[37] Original projections were to 2050; I projected out to 2060 using the annual growth rates provided. These figures might be somewhat rosy; more recently, the US Census Bureau projected that world population will grow from 6 billion in 1999 to 9 billion by 2040. See US Census Bureau, "World Population: 1950–2050," International Data Base (2009).

possibility) would create 4.05 population *de* stabilization wedges and almost certainly doom efforts to mitigate catastrophic GCC. These figures show that reducing population growth could make a huge contribution to mitigating GCC.[38]

"Population control" tends to bring to mind coercive measures, such as forced abortions or sterilizations. In fact there are non-coercive policies that are almost as effective at reducing birthrates, and these are the ones we should pursue in constructing population wedges. First, providing free or low-cost birth control and accessible, appropriate information about how to use it has proven very effective in lowering birthrates in many poor countries.[39] Providing cheap birth control allows those who want to have fewer children to do so, increasing reproductive freedom while decreasing population growth. Second, policies which improve the lives of women have been shown to reduce fertility rates in many developing countries.[40] These include guaranteeing girls the same educational opportunities as boys, promoting female literacy, and improving women's economic opportunities (and thus their value and status in society). Third, making abortion safe, legal, and easily available has helped reduce birthrates in many countries. In fact, no modern nation has stabilized its population without legalizing abortion. All these measures can directly improve people's lives at the same time that they help reduce population growth.

Given that these non-coercive methods have proven successful at reducing fertility rates in many places, and given the huge unmet need for contraception throughout the developing world, well-funded efforts to apply them globally seem capable of reducing population growth from the "most likely" scenario of 9.6 billion people to the lower projection of 8 billion people in 2060. Once again: 1.6 billion fewer people 50 years from now represents 2.95 carbon reduction wedges. That would make an immense contribution to mitigating GCC, equal to deploying all three of Pacala and Socolow's carbon capture and sequestration wedges. Unlike carbon capture, however, the proposed population reduction measures rely on proven technologies that are available right now. Population wedges would also provide numerous other environmental benefits, reducing

[38] Frederick Meyerson, "Population, Carbon Emissions, and Global Warming: The Forgotten Relationship at Kyoto," *Population and Development Review*, 24 (1998), pp. 115–130; O'Neill *et al.*, *Population and Climate Change*, ch. 6.

[39] Joseph Speidel *et al.*, *Making the Case for U.S. International Family Planning Assistance* (New York: Population Connection, 2009).

[40] Carmen Barroso, "Cairo: The Unfinished Revolution," in Laurie Mazur (ed.), *A Pivotal Moment*, pp. 245–259.

human impacts across the board, in contrast to the massive environmental harms that would be caused by continued coal and uranium mining under the carbon and nuclear power wedges, or the smaller but still substantial environmental harms caused by large-scale wind or solar power generation. Smaller populations would also make an important contribution longer-term, as humanity moves closer (we hope) to creating truly sustainable societies. *Ceteris paribus*, smaller human populations are more likely to be sustainable, while endlessly growing populations are unsustainable by definition.[41]

Securing women's rights and furthering their opportunities are the right things to do, independent of their demographic effects; they can also effectively help stabilize human numbers. Population wedges thus provide "win/win" scenarios with the potential to aid women and their families directly, increasing their happiness and freedom, while helping meet the grave danger of GCC.[42] Some of the very same aims written into the UN's Millennium Development Goals, such as improving maternal health and increasing the percentage of children receiving a full primary school education, turn out to be among the most effective means to reduce birth rates in poor countries.[43] In addition, a recent study from the London School of Economics, titled *Fewer Emitters, Lower Emissions, Less Cost*, argues that reducing population growth is much cheaper than many other mitigation alternatives under consideration.[44] Given all this, policies to stabilize or reduce populations should be an important part of national and international climate change efforts. These are some of the best wedges we've got.

Still, talk of limiting or reducing human numbers makes some people uncomfortable. Many of us have held a newborn baby and felt a sense of infinite possibility and value radiating out from that little form. How could the world possibly be better without him or her? Nevertheless, most of us do not have as many children as we are biologically capable of having. Resources are limited. There are high human costs when urban populations outgrow basic services, or large numbers of young people go unemployed; meanwhile, even confirmed anthropocentrists might well hesitate before accepting the total displacement of wild nature in order to maximize human

[41] Albert Bartlett, "Reflections on Sustainability, Population Growth and the Environment," in Marco Keiner (ed.), *The Future of Sustainability* (Dordrecht: Springer, 2006).

[42] Brian O'Neill, "Cairo and Climate Change: A Win/Win Opportunity," *Global Environmental Change*, 10 (2000), pp. 93–96.

[43] Colin Butler, "Globalisation, Population, Ecology and Conflict," *Health Promotion Journal of Australia*, 18 (2007), p. 87.

[44] Thomas Wire, *Fewer Emitters, Lower Emissions, Less Cost: Reducing Future Carbon Emissions by Investing in Family Planning: A Cost/Benefit Analysis* (London: London School of Economics, 2009).

numbers. People are wonderful, but it is possible to have too many people: in a family, a city, or a nation. GCC may be showing us that it is possible to have too many people on the Earth itself. Part of its message may be that with freedom to reproduce comes responsibility to limit reproduction, so as not to overwhelm global ecological services or create a world that is solely a reflection of ourselves.

5 ALTERNATIVE WEDGES: GROWTH

According to the US Department of Energy (DOE), "economic growth is the most significant factor underlying the projections for growth in energy-related carbon dioxide emissions in the mid-term, as the world continues to rely on fossil fuels for most of its energy use."[45] This suggests that one way to limit increased greenhouse gas emissions is to directly limit economic growth. In its report "International Energy Outlook 2009," the DOE quantifies the impact of various growth rates on carbon emissions out to 2030 as follows: at a high (4 percent) annual growth rate, energy use and CO_2 emissions both increase 1.8 percent annually; at a medium "reference" (3.5 percent) annual growth rate, energy use increases 1.5 percent annually and CO_2 emissions increase 1.4 percent annually; and at a low (3 percent) annual growth rate, energy use increases 1.2 percent annually and CO_2 emissions increase 1.0 percent annually.[46] The difference between a 3 percent or percent annual growth rate adds up to 1.94 billion fewer metric tons of carbon emitted annually by 2030, or 19 percent less. By my calculations, limiting annual world economic growth to 3 percent rather than 4 percent over the next 50 years would lead to 73.64 metric tons less carbon emitted, or almost three carbon reduction wedges.

Both monetary policy and fiscal policy can be used to ratchet back growth. For example, central banks routinely tighten money supplies when rapid growth threatens to cause high inflation. This raises interest rates, reduces borrowing and spending, and slows overall growth. Conservative, Chicago school economists argue bitterly with liberal Keynesians over whether monetary policy should primarily seek to control inflation, or whether it is also a proper tool for fighting unemployment. Happily, you can make a temporary peace between these warring factions by proposing that growth rates be manipulated to influence carbon

[45] United States Energy Information Administration, Department of Energy, "International Energy Outlook 2009" (Washington, DC: 2009), ch. 1.
[46] Ibid.

emissions: Both sides will likely agree that you are crazy. More than once, economists have asked me "whether I want us all to live in caves?" when I've suggested that slowing growth might be part of slowing GCC. Still, once we have the idea that economic growth may be limited to further other important goals, the question becomes: which goals are important enough to trump growth? Preventing global ecological disaster would seem to be a good candidate.

Granted it sounds odd to say, "Let's embrace lower rates of wealth creation." For one thing, it makes hard choices about the fair allocation of resources even harder. For another, you are arguing for putting fewer overall resources at a society's command, and why would fewer resources be better? Well, here are two possible reasons. First, standard measures of economic growth lump all wealth together under a single monetary metric. But if by increasing overall resources, we lose some resources essential to our survival or well-being, we've failed, even if the financial balance sheet reads otherwise.[47] Second, we arguably also fail if in producing more total wealth, we harm poor people or future generations, or drive other species to extinction, through climate change. For what profits it a man if he gains the whole world and loses his soul? What profits it this current, wealthy generation of men and women if we beggar our grandchildren, other defenseless people, or nature itself?

Directly reducing economic growth – by far the leading cause of GCC – is both possible and potentially very effective in reducing greenhouse gas emissions. Like similar efforts to fight inflation, reducing growth to fight GCC could be done in a limited and controlled way. It is telling that such an obvious wedge candidate is almost totally overlooked in analyses of the problem. To quote once again from the fourth assessment report: "The challenge – an absolute reduction of global GHG emissions – is daunting. *It presupposes a reduction of energy and carbon intensities at a faster rate than income and population growth taken together*. Admittedly, there are many possible combinations of the four Kaya identity components, but with the scope and legitimacy of population control subject to ongoing debate, the remaining two technology-oriented factors, energy and carbon intensities, have to bear the main burden."[48] While the report's authors punt on population control, at least they mention it. They don't even seem aware

[47] The *Millennium Ecosystem Assessment* discusses this issue at length. For a recent attempt to specify better measurements of economic and social progress, see Joseph Stiglitz *et al.*, *Draft Report* (Commission on the Measurement of Economic Performance and Social Progress, 2009).

[48] IPCC, *Climate Change 2007: Mitigation*, Technical Summary, p. 109; emphasis added.

that we have a choice about whether or not to ease up on the pedal of economic growth. By defining "the challenge" of GCC as reducing greenhouse gas emissions while still accommodating endless growth, they avoid hard questions regarding the reigning economic orthodoxy – but only at the cost of rendering their problem unsolvable.

GCC should have awoken economists and the rest of us from our dogmatic slumbers regarding the goodness of maximal growth and the sustainability of endless growth.[49] As Tim Jackson writes in a recent report to the European Union Sustainable Development Commission, *Prosperity Without Growth? The Transition to a Sustainable Economy*, "The truth is that there is as yet no credible, socially just, ecologically-sustainable scenario of continually growing incomes for a world of nine billion people. In this context, simplistic assumptions that capitalism's propensity for efficiency will allow us to stabilize the climate or protect against resource scarcity are nothing short of delusional."[50] We can and should work to decouple economic growth from carbon emissions, but to assume we will achieve a complete decoupling anytime soon is irresponsible.

Clearly, we will need a new economic paradigm in order to create sustainable societies.[51] It is beyond the scope of this paper to wade into the debate about whether a truly sustainable economy must be post-growth, slow-growth, no-growth, or something else.[52] Here I make the more limited point that reducing (still relatively high) economic growth rates in the near- and midterm could make a significant contribution to reducing greenhouse gas emissions and avoiding catastrophic GCC. We don't "all have to live in caves" in order to do that.

[49] A few economists are awake to limits to growth, but the great majority is not. See Garrett Hardin, *Living Within Limits: Ecology, Economics, and the Population Taboos* (New York: Oxford University Press, 1993).

[50] Tim Jackson, *Prosperity Without Growth? The Transition to a Sustainable Economy* (European Union Sustainable Development Commission: 2009), p. 57.

[51] Valuable contributions to specifying the parameters of a sustainable economy include Herman Daly and John Cobb, *For the Common Good: Redirecting the Economy Toward Community, the Environment, and a Sustainable Future* (Boston: Beacon Press, 1989); and Samuel Alexander (ed.), *Voluntary Simplicity: The Poetic Alternative to Consumer Culture* (Whanganui, New Zealand: Stead & Daughters, 2009).

[52] There is a strong argument that economic growth can benefit poor societies, but it is funny how quickly economists turn the discussion to sub-Saharan Africa or Haiti, when anyone questions the need for continued growth in the overdeveloped world. See McKibben, *Deep Economy*, for an argument that economic growth no longer benefits people in wealthy contemporary societies such as the USA. McKibben admirably summarizes the scholarly evidence for this conclusion and clearly lays out the key issues. He also demonstrates that accepting limits to economic growth need not lead to personal or community stagnation. After all, increasing wealth, consumption, or numbers is neither the only nor the most important way people, or peoples, can grow.

6 COMPARING ALTERNATIVES

Table 3 shows the alternative carbon reduction wedges I have proposed in this paper; doubtless more are possible:

All the wedges outlined above are achievable using current technologies. As with Pacala and Socolow's more conventional wedges, pushing reductions faster and further could result in additional wedges, while implementing some wedges limits the potential savings from others. My proposal is not to replace the original list with my alternative, but to combine the two, increasing our options.

Providing more wedges is important because we might have to consider relatively unpalatable choices, now that scientists are telling us we may have to ratchet down emissions faster than anticipated in order to avoid catastrophic GCC. However, some alternative wedges might actually be preferable to the usual proposals to mitigate GCC. For example, it is not clear

Table 3 *Potential alternative carbon mitigation wedges*

	Option	Effort by 2060 for one wedge, relative to 15 gigatons of carbon per year (GtC/year) under business as usual
Consumption reduction	1. Eating less meat	Prevent half the projected world increase in meat eating
	2. Flying less often	Prevent one-third of the projected increase in commercial aviation
	3. – 9. Taxing carbon	Tax greenhouse gas emissions at $50 per metric ton of CO_2 equivalent (a conservative estimate of the carbon reductions available using this method)
	10. Limiting luxury consumption	Tax or prohibit multiple personal plane flights, large homes, low-mileage vehicles, or other unnecessary consumption
Population stabilization/ reduction	11. – 13. Improving women's lives and reproductive freedom	Achieve UN's low rather than medium 2060 population projection (8.0 rather than 9.6 billion) by providing free, accessible birth control and improving women's economic and educational opportunities
Economic growth reduction	14. – 16. Limiting the size of the world economy	Use monetary and fiscal policy to reduce growth rates from 4% to 3% annually (could be pushed further, providing more wedges)

that tripling the world's nuclear generating capacity is superior to simply cutting back on electricity use by reducing unnecessary consumption. Cutting consumption might be cheaper and less dangerous, and make a stronger contribution to creating sustainable societies. Again, some of us would prefer that our tax dollars go toward helping poor women in developing countries improve their lives, as in the population reduction wedges, rather than subsidizing energy companies' profits, as required by Pacala and Socolow's coal and nuclear wedges. Again, limiting consumption and population growth seems less selfish and more responsible than relying solely on efficiency improvements that pass significant environmental harms on to nonhuman beings and future generations, or on futuristic technologies that may not work.

Whether or not I'm right in these particular judgments, getting a full range of alternatives on the table would seem to be our best hope for finding the fairest and most efficient strategies to mitigate GCC. Pacala and Socolow's original framework allows us to consider whether to triple nuclear generating capacity or build 2 million new wind turbines; the expanded framework allows us to choose these options, or the option of paying more for electricity and using less of it. The original framework makes it hard to achieve eight wedges without committing to continued heavy use of coal; the expanded framework would allow humanity to phase out coal and uranium as fuel sources, provided we embrace population reduction. The new framework thus makes explicit some of the ecological and economic costs of continued consumption and population growth, and emphasizes that such growth is a choice.

As in the original framework, alternatives can be compared regarding monetary cost, total ecological impact (not just impacts on greenhouse gas emissions), and social equity. But now new alternatives are in play that would further sustainability, improve the lives of some of the world's poorest people, and demand greater contributions from wealthy global elites. My claim is that using this expanded list of wedges would allow us to come up with a better (because more just and more sustainable) climate change policy, and also that implementing more alternative wedges would put us in a better position to transition to truly sustainable societies in the second half of the twenty-first century.

7 CONCLUSION

A strength of the wedge approach is that it fosters intelligent choices among alternative courses of action. However, we need to expand the discussion to

include alternatives that directly address the main forces driving GCC: increasing consumption, increasing populations, and rapid economic growth. Our continued failure to do so could lead to catastrophic GCC and delay the necessary transition to ecological sustainability.

Comparing alternative mitigation scenarios, done correctly, should make the ethical commitments behind our choices explicit. My own belief is that the best response to GCC is one that protects and enhances the flourishing of all life, human and nonhuman.[53] So in considering alternative courses of action, I believe we should choose wedges that:

* reduce the human appropriation of habitats and resources needed by other species, rather than increasing such appropriation
* avoid compromising the abilities of poor people to provide for their basic sustenance and well-being
* avoid relying on unproven technologies, or technologies that increase the risk of unintended or unexpected consequences.

Mindful of GCC's immense potential harms and the diminishing returns of increased wealth and consumption in wealthy nations, I would argue for more wedges rather than fewer. Looking to long-term sustainability, I would embrace some of Pacala and Socolow's technological efficiency wedges, but supplement them with wedges that build up our societies' capacities for demographic and economic restraint. The virtue of temperance is intrinsically valuable – commendable in itself, in a person or a nation – and its instrumental value will only increase in the more crowded and damaged world that we are busy making.[54] In order to create truly sustainable societies, we will need to become wiser, as well as more clever.[55]

[53] Philip Cafaro, "Thoreau, Leopold and Carson: Toward an Environmental Virtue Ethics," *Environmental Ethics*, 23 (2001), pp. 3–17; Eileen Crist, "Beyond the Climate Crisis: A Critique of Climate Change Discourse," *Telos*, 141 (2007), pp. 29–55.

[54] Joshua Gambrel and Philip Cafaro, "The Virtue of Simplicity," *Journal of Agricultural and Environmental Ethics*, 23 (2010), pp. 85–108.

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