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TOWARD A NET-ZERO CARBON PLANET: A POLICY PROPOSAL

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The effort to address climate change is global in scale and increasingly urgent, yet it lacks an effective policy framework. President Obama's determination to elevate clean energy to a national policy priority, Congress's consideration of a federal cap-and-trade regime for greenhouse gases, and the upcoming revisions to the Kyoto Protocol all provide an opportunity to move toward adopting a globally balanced carbon budget. A balanced carbon budget could replace the current, somewhat arbitrary greenhouse gas reduction targets with a scientifically derived calibration limiting global carbon emissions to the rate of carbon absorption. Carbon sub-budgets could then be allocated to each nation or region, which could choose its own measures to meet its carbon budget through a carbon-management plan. These measures will likely fall into four broad categories: reduction of carbon emissions through demand reduction and greater efficiency; increased carbon absorption through reforestation and carbon capture; substitution of non-carbon-based fuels; and, because of the lag time in achieving carbon equilibrium through implementing these measures, adaptation to climate change. Such a balanced carbon budget approach has the virtues not only of long-term safety, but also of clarity, comprehensiveness, and choice. Recent experience shows that choice—allowing units of government and industry flexibility in meeting budget targets—is the key to gaining and retaining public support and to harnessing ingenuity and innovation. This overall approach requires an unprecedented level of monitoring, reporting, and adjustment to achieve the desired result. It may also require some departures from current environmental orthodoxies favoring smart growth and opposing nuclear power.

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INTRODUCTION

The looming threat of climate change makes reducing greenhouse gas emissions to sustainable levels while maintaining a reasonable quality of life perhaps the central challenge of our time.[1] Its scale requires structural adjustments to economies and societies across the globe. The increasing sense of urgency about addressing climate change, combined with the uncertainty as to how to go about it, creates great anxiety among those who accept the necessity of action. This uncertainty also undermines efforts to persuade others who do not yet accept the need for action.

With breathtaking speed, we have gone from a federal government that largely denied the reality of human-induced climate change to one that has elevated it to a major policy priority.[2] Congress is now considering "cap-and-trade" legislation that would create a national program limiting total greenhouse gas emissions and allow major emitters to sell any surplus allocation gained through emissions reductions.[3] Additionally, nations will debate the terms of renewing the Kyoto Protocol,[4] which is set to expire in 2012, at the UN Climate Conference in Copenhagen this December.

This important policy moment highlights the need to move toward a comprehensive and comprehensible climate change policy framework to replace the bewildering profusion of measures and strategies being debated or tested in piecemeal fashion across all levels of government and sectors of the econo-

1. *See generally* THOMAS L. FRIEDMAN, HOT, FLAT, AND CROWDED: WHY WE NEED A GREEN REVOLUTION—AND HOW IT CAN RENEW AMERICA (2008) (noting the broad effect of the global environmental crisis on daily life); JEFFREY D. SACHS, COMMON WEALTH: ECONOMICS FOR A CROWDED PLANET (2008) (citing climate change as one of the four biggest challenges of the coming decade).

2. While the Bush administration opposed any broad effort to address climate change, according to press reports, the Obama administration's proposed fiscal year 2010 budget projects almost $80 billion in revenue in 2012 from the sale of greenhouse gas emissions permits, thus presuming that a federal cap-and-trade regime will be functioning by then. Jonathan Weisman, *Climate-Bill Breaks Bode Ill for Deficit*, WALL ST. J., May 12, 2009, at A3, *available at* http://online.wsj.com/article/SB124204820923806673.html.

3. American Clean Energy and Security Act of 2009, H.R. 2454, 111th Cong. (2009), *available at* http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=111_cong_bills&docid=f:h2454ih.pdf.

4. Kyoto Protocol to the United Nations Framework Convention on Climate Change, Dec. 11, 1997, *available at* http://unfccc.int/resource/docs/convkp/kpeng.pdf.

my.[5] This Essay posits that the most effective long-term policy framework is to establish a science-based, balanced global carbon budget and then to allocate it down to manageable units of government, industry, and even neighborhoods, giving them freedom to choose how to meet their carbon sub-budget within an established time frame.

Such an approach replaces uncertainty with clarity and breaks the problem down to an actionable scale. It also allows a choice of remedies, which unlocks ingenuity, resourcefulness, and adaptability.[6] To illuminate this proposal, this Essay begins by reviewing the basic science behind anthropogenic climate change. It then describes how a balanced carbon budget policy approach could address climate change through carbon-management plans, which include measures for greenhouse gas reduction, substitution, absorption, and adaptation. The Essay ends with several observations about the implications of this approach with respect to existing policy efforts.

I. FOLLOW THE CARBON

It will be helpful to start at the beginning of the problem. As summarized by a United Nations panel that studied climate change in detail,[7] the carbon-laden gases released by burning fossil fuels for buildings, transportation, industry, and agriculture trap the sun's energy and alter the atmosphere and climate in unpredictable ways.[8] There is a significant lag time—maybe decades—between the release of carbon and its effect on the climate at the earth's surface where we live.[9] Carbon is al-

5. *See* Stephen M. Wheeler, *State and Municipal Climate Change Plans: The First Generation*, 74 J. AM. PLAN. ASS'N 481, 481–82 (2008).

6. *See generally* RICHARD H. THALER & CASS R. SUNSTEIN, NUDGE: IMPROVING DECISIONS ABOUT HEALTH, WEALTH AND HAPPINESS 185–88 (2008) (discussing the uses of "choice architecture" in achieving public policy goals).

7. *See generally* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: SYNTHESIS REPORT (2007), *available at* http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm [hereinafter SYNTHESIS REPORT] (summarizing major findings from the Nobel Peace Prize winning report).

8. *See* WORKING GROUP I, INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS 677 (Susan Solomon et al. eds., 2007), *available at* http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg1_report_the_physical_science_basis.htm [hereinafter PHYSICAL SCIENCE BASIS].

9. Gerald A. Meehl et al., *How Much More Global Warming and Sea Level Rise?*, 307 SCIENCE 1769, 1769–72 (2005) (explaining how thermal inertia would continue to cause sea-level rise after greenhouse gas emissions stabilize).

so released by natural processes like decay of vegetation, forest fires, and even animal flatulence. This atmospheric carbon is slowly absorbed by photosynthetic plants, including oceanic plankton.[10] There have been natural climate fluctuations over millennia, but human activity has dramatically altered the balance in the last hundred years. During this time we have been burning fossil fuel, increasing atmospheric levels of carbon dioxide from about 280 parts per million to 379 parts per million,[11] with increasingly volatile climate effects.

We can address this predicament both by reducing the rate of greenhouse gas emissions—for example, through more energy-efficient buildings and more fuel-efficient cars—and by increasing the rate of absorption, through such measures as reforestation or carbon sequestration.[12] However, based on current technology, increases in efficiency alone will not be enough to match the absorption rate and, furthermore, could rapidly be offset by population and economic growth.[13]

Consequently, in addition to increasing carbon absorption and reducing carbon emissions, we must increasingly substitute non-carbon-based fuels for fossil fuels. This substitution could include not only renewable sources—wind, solar, geothermal, and water power—but also emerging technologies such as hydrogen fuel cells, which produce both energy and water,[14] and perhaps nuclear power, if we can assure safety and address the siting of spent fuel storage.

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10. WORKING GROUP II, INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: IMPACTS, ADAPTATION AND VULNERABILITY 227–34 (Martin Parry et al. eds., 2007), *available at* http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg2_report_impacts_adaptation_and_vulnerability.htm [hereinafter IMPACTS, ADAPTATION AND VULNERABILITY] (noting the carbon sequestration effects of photosynthetic plants in various ecosystems, including forests and oceans).

11. SYNTHESIS REPORT, *supra* note 7, at 37.

12. *See, e.g.*, IMPACTS, ADAPTATION AND VULNERABILITY, *supra* note 10, at 227–34. Large-scale geo-engineering proposals to interrupt the climate effects of greenhouse gas emissions are highly controversial due to their unpredictable side effects. *See, e.g.*, Graeme Wood, *Moving Heaven and Earth*, ATLANTIC, July–Aug. 2009, at 70, 70, 72–73, 76; Posting of John Lorinc to Green Inc., http://greeninc.blogs.nytimes.com/2009/06/01/tweak-the-planet-to-curb-warming-not-yet/ (June 1, 2009, 9:48 EST).

13. *See* SACHS, *supra* note 1, at 29–30; MCKINSEY & CO., PATHWAYS TO A LOW-CARBON ECONOMY: VERSION 2 OF THE GLOBAL GREENHOUSE GAS ABATEMENT COST CURVE 12 (2009), *available at* http://www.climateworks.org/case_studies/PathwaysToLowCarbonEconomy_FullReport.pdf.

14. It seems almost too good to be true that in place of burning dead life forms to create both energy and heat-trapping gas, we can instead combine the atmosphere's most plentiful elements, hydrogen and oxygen, to create energy and water,

Deploying these strategies to achieve long-term climate equilibrium by limiting carbon emissions to the rate of absorption contrasts with the current global framework for addressing climate change. The current approach, reflected in the Kyoto Protocol, is based on target reductions in greenhouse gas emissions over 1990 levels. These targets have been described, however, as political targets rather than science-based ones.[15]

Similarly, existing state or regional cap-and-trade regimes are based on a cap on total carbon emissions from major sources such as power plants and heavy industry, which are then reduced over time.[16] But these caps are generally based on historic emissions levels,[17] which can only be estimated,[18] and the schedule and amount of reductions are inconsistent.[19] While the exact contours of a federal cap-and-trade regime remain unknown, the Waxman-Markey bill passed by the United States House of Representatives, and now under consideration in the United States Senate, also proposes reductions from 2005 emission levels.[20]

More important, to date there is no scientific consensus about the precise level of atmospheric carbon that will induce an unacceptable level of climate change, about whether or when irreversible "tipping points" may be reached, or even about the level of climate change that would be acceptable.[21]

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and indeed the technology still has a way to go before it is commercially feasible. MCKINSEY & CO., *supra* note 13, at 96–103.

15. *See* John Lanchester, *Hot Air*, 29 LONDON REV. BOOKS 3, 3–9 (2007). While the IPCC Fourth Assessment Report identifies so-called "carbon sinks" such as the oceans and tropical rainforests and estimates their absorption capacity, it does not explicitly link target reductions to this absorption capacity. *See* IMPACTS, ADAPTATION AND VULNERABILITY, *supra* note 10, at 233–37.

16. *See, e.g.*, Climate Protection and Green Economy Act, MASS. GEN. LAWS ANN. ch. 21N (West 2009) (mandating such reductions).

17. *See id.* § 3.

18. *See, e.g.*, California Global Warming Solutions Act of 2006, CAL. HEALTH & SAFETY CODE § 38550 (West 2009) (requiring the state board to estimate the 1990 emissions levels by evaluating "scientific, technological, and economic information").

19. *Compare* California Global Warming Solutions Act of 2006, CAL. HEALTH & SAFETY CODE § 38550 (West 2009) (requiring a reduction to 1990 levels by 2020) *with* Climate Protection and Green Economy Act, MASS. GEN. LAWS ANN. ch. 21N, § 4 (West 2009) (requiring a reduction to 10 to 25 percent below 1990 levels by 2020).

20. American Clean Energy and Security Act of 2009, H.R. 2454, 111th Cong. §§ 301, 311 (2009), *available at* http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=111_cong_bills&docid=f:h2454ih.pdf.

21. Some scientists, such as James Hansen, Director of NASA's Goddard Institute for Space Studies, believe we have already passed the point of "dangerous

In fact, the earth's climate is sufficiently complex that it may be unrealistic to expect definitive answers to these questions in the time available to act. This uncertainty makes following the Precautionary Principle, which shifts to proponents the burden of proof for actions that could cause serious or irreversible harm to the public or the environment, all the more appealing.[22] In the absence of contrary proof, assuring the long-term safety and security of human life on the planet requires not merely reductions in emissions from historic emission levels, the effect of which can only be guessed, but rather, bringing atmospheric carbon into long-term equilibrium through the three strategies of absorption, reduction, and substitution.

But, since further climate change is inevitable and we do not yet know how long it will take to achieve carbon equilibrium through transitioning to a balanced carbon budget, adaptation is an important fourth strategy. With the uncertainty as to the efficacy of the current policy approach, working towards a planetary balanced carbon budget should be a major national, if not global, priority.[23]

Therefore, as some 170 participating countries prepare to debate renewal of the Kyoto Protocol in Copenhagen,[24] this is an appropriate time to lay groundwork for a new climate change framework based on the goal of achieving a globally-balanced carbon budget within a defined time frame—say by 2050, the target year used by the Intergovernmental Panel on Climate Change and the Waxman-Markey proposed legislation.[25] The total global cap based on the rate of absorption, and the rate of reduction required to achieve it, would initially be based on the best estimates currently available and would

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anthropogenic interference." Elizabeth Kolbert, *The Catastrophist*, NEW YORKER, June 29, 2009, at 39, 42.

22. *See* Phillip M. Kannan, *The Precautionary Principle: More Than a Cameo Appearance in United States Environmental Law?*, 31 WM. & MARY ENVTL. L. & POL'Y REV. 409, 418–21 (2007).

23. This mirrors the approach now being explored in the building sector to create "net zero energy" buildings that generate as much power as they consume. *See* MASS. NET ZERO ENERGY BLDGS. TASK FORCE, GETTING TO ZERO: FINAL REPORT OF THE MASSACHUSETTS NET ZERO ENERGY BUILDINGS TASK FORCE (2009), *available at* www.mass.gov/Eoeea/docs/eea/press/publications/zneb_taskforce_report.pdf (providing recommendations for developing commercial and residential "net zero energy" buildings).

24. Copenhagen 2009, Climate Conference in Copenhagen, http://www.erantis.com/events/denmark/copenhagen/climate-conference-2009/index.htm (last visited Aug. 7, 2009).

25. *See, e.g.*, SYNTHESIS REPORT, *supra* note 7, at 67; H.R. 2454 § 132(b).

build in a periodic adjustment mechanism as new information emerges.[26]

II. DEVOLUTION

Once a balanced planetary carbon emissions budget is scientifically derived by measuring carbon absorption, the next step would be a political rather than a scientific challenge: establishing a method to allocate this planetary carbon budget among countries, similar to how Kyoto currently sets reduction targets for each country.[27] It is not the purpose of this Essay to suggest such an allocation mechanism, although the method must ultimately take into account the fact that current per capita carbon emissions, as well as the opportunities and resources for carbon reduction, substitution, and absorption, are unevenly distributed across the globe.[28] Perhaps a global cap-and-trade mechanism among countries or regions can help even out these disparities.

Suppose we make the exhilarating assumption that participating countries have agreed to an allocation mechanism and, as a result, that the United States has an annual carbon budget, with freedom to determine how to meet this budget and an obligation to report the results to an international monitor annually. To promote experimentation and innovation, this national budget could be further devolved to each state, in the way that the Environmental Protection Agency has delegated authority to states to implement the provisions of the Clean Air Act through State Implementation Plans.[29] Moreover, the states could decide to further allocate their budgets to munici-

26. *See, e.g.*, Climate Protection and Green Economy Act, MASS. GEN. LAWS ANN. ch. 21N, § 5 (West 2009) (requiring assessment reports on emission reduction strategies every five years).

27. *See* Kyoto Protocol to the United Nations Framework Convention on Climate Change, Article 3 § 1, Dec. 11, 1997, *available at* http://unfccc.int/resource/docs/convkp/kpeng.pdf.

28. Weak or failed states may be unable to enforce any such regime. *See* WORKING GROUP III, INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: MITIGATION OF CLIMATE CHANGE 178 (Bert Metz et al. eds., 2007), *available at* http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg3_report_mitigation_of_climate_change.htm [hereinafter MITIGATION OF CLIMATE CHANGE]. Such states tend to have low carbon footprints, however, and their share could perhaps be allocated to larger emitters. *See* United Nations Development Programme, Inequalities in Carbon Footprinting—Some People Walk More Lightly than Others, http://hdr.undp.org/en/statistics/data/climatechange/footprints (last visited Aug. 7, 2009).

29. *See, e.g.*, Clean Air Act, 42 U.S.C. § 7410 (2006).

palities or regions. Just as a large corporation or university has divisions or departments, each living within its own budget, municipalities could sub-allocate to industry sectors (such as buildings or transportation) or to neighborhoods, and so on.

The level of devolution would vary based on the allocation method chosen. While it would not make sense to allocate electric utility emissions by municipality since most power plants send power across regional electric grids, it would make sense to allocate emissions from buildings by city or even by neighborhood since their emissions are in fixed locations.[30] Each compliance unit would then develop its own suite of measures to achieve the target emissions level effectively through "carbon management plans."

Hundreds of United States mayors have now signed on to the U.S. Mayors Climate Protection Agreement,[31] and many large cities, including Boston, Chicago, New York, and Seattle, have adopted their own climate action plans.[32] But these plans represent largely aspirational measures focused on the carbon footprint of city government itself.[33] They lack common methodologies, and most importantly, they lack rigorous monitoring and reporting mechanisms.[34] If instead these plans were tied to an annual carbon budget, had a dedicated source of funding,[35] and had rigorous monitoring and reporting components, they could more strongly impact both municipal and private actors. Similarly, the current private plans of companies such as Timberland[36] and educational institutions such as

30. Alice Kaswan, *Climate Change, Consumption, and Cities*, 36 FORDHAM URB. L.J. 253, 297–98 (2009).

31. U.S. CONFERENCE OF MAYORS, THE U.S. MAYORS CLIMATE PROTECTION AGREEMENT (2005), *available at* http://usmayors.org/climateprotection/documents/mcpAgreement.pdf.

32. *See, e.g.*, CITY OF BOSTON, CLIMATE: CHANGE (2007), *available at* http://www.cityofboston.gov/climate/pdfs/CAPJan08.pdf; CITY OF CHICAGO, CHICAGO CLIMATE ACTION PLAN (2008), *available at* http://www.chicagoclimateaction.org/filebin/pdf/finalreport/CCAPREPORTFINAL.pdf; CITY OF N.Y., PLANYC: A GREENER, GREATER NEW YORK (2007), *available at* http://www.nyc.gov/html/planyc2030/downloads/pdf/full_report.pdf; CITY OF SEATTLE, SEATTLE, A CLIMATE OF CHANGE: MEETING THE KYOTO CHALLENGE (2006), *available at* http://www.seattle.gov/climate/docs/SeaCAP_plan.pdf.

33. *See, e.g.*, CITY OF BOSTON, *supra* note 32, at 23 (providing that the City shall report annually on energy consumption and greenhouse gases, where applicable).

34. *See id.*

35. *See infra* Part V (discussing funding mechanisms).

36. TIMBERLAND, TIMBERLAND CLIMATE STRATEGY: IT'S THE SHOES WE CRAFT AND THE OUTDOORS WE CRAFT THEM FOR (2009), *available at* http://www.timberland.com/corp/Timberland_Climate_Strategy_2009_report.pdf.

Harvard University[37] could fit into a larger policy framework, rather than being self-generated, non-binding, and inconsistent in their goals and assumptions.

III. SOURCES AND USES

Each carbon-management plan would vary in its measures to meet an overall carbon sub-budget. As a preliminary matter, in order to understand where the greatest opportunities for reduction lie, it is worth addressing the principal sources of carbon emissions and the principal uses of carbon-based energy. Once measurement protocols for these emissions sources are established, the contributions of each major source and user to the carbon sub-budget can be determined.

In the United States, for example, the major sources of carbon emissions are electric-generating plants;[38] oil and natural-gas-fired building boilers and furnaces; industrial facilities; agriculture; landfills that emit the greenhouse gas methane as organic matter decomposes; and transportation of all forms, including planes, trains, buses, trucks and automobiles.[39]

While much carbon-based energy is used where it is generated, such as for cars and building-heating plants, this is generally not the case with electric power, which is mostly generated at remote power plants and transmitted to where it is used. Therefore, in developing carbon-management plans, it is also instructive to address the activities that use the most carbon-based energy, thus emitting the most greenhouse gases. While figures vary somewhat as to how much each of these sectors uses, the big three users of carbon-based energy are buildings for lighting, heating, cooling, and appliances; transportation; and industry, including agriculture.[40] We must monitor and quantify these sources and uses of carbon-based energy according to standard measurement and reporting protocols in order to develop effective carbon-management plans.

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37. HARVARD UNIV. TASK FORCE ON GREENHOUSE GAS EMISSIONS, REPORT OF THE HARVARD UNIVERSITY TASK FORCE ON GREENHOUSE GAS EMISSIONS (2008), *available at* www.news.harvard.edu/gazette/2008/07.24/pdfs/GHG_TF_finalreport.pdf.

38. Approximately 70% of U.S. electricity is generated from fossil fuels. ENERGY INFO. ADMIN., U.S. DEP'T OF ENERGY, ANNUAL ENERGY REVIEW 2008 228 fig.8.2a (2009), *available at* http://www.eia.doe.gov/aer/pdf/aer.pdf [hereinafter ANNUAL ENERGY REVIEW].

39. *See id.* at 350–57 figs.12.3, 12.4, 12.5 & 12.6.

40. *See* ANNUAL ENERGY REVIEW, *supra* note 38, at 37–65.

IV. CARBON-MANAGEMENT PLANS

This background information, although conceptual and incomplete, provides a framework for shaping carbon-management plans deploying the three main strategies for climate protection—reduction of greenhouse gas emissions, substitution of non-carbon-based fuels, and increased absorption of atmospheric carbon—across each major source and user group according to defined budget targets.

An example will best illustrate this approach. Imagine the building sector in the Commonwealth of Massachusetts is allocated an annual carbon budget of ten million tons. The sector can meet this target through any combination of reductions, substitutions, and absorptions, including measures such as energy retrofits of existing buildings, distributed generation, green roofs, or solar photovoltaic power. Meeting the target would not need to be accomplished on-site, as long as both off-site emissions (such as from power plants) and off-site mitigation (such as from reforestation) can be taken into account.[41]

Similarly, the transportation sector can use some combination of transit investments, offsets for air travel (for which there is currently no non-carbon substitute[42]), and electric, hybrid, or fuel-cell vehicles to achieve its allocations. McKinsey & Company, a U.S.-based global management consulting firm, has already performed a helpful cost-benefit analysis identifying which strategies accomplish the greatest greenhouse gas reductions at the lowest cost.[43] Of course, the most cost-effective measures are likely to change as technology improves and consumption habits evolve.

As noted above, a fourth strategy, adaptation, must also be addressed. Because we will not quickly achieve a balanced carbon budget, and because of the lag time between already-released carbon and its climate effects, we have several decades

41. *See generally* MASS. NET ZERO ENERGY BUILDINGS TASK FORCE, *supra* note 23; WORLD BUS. COUNCIL FOR SUSTAINABLE DEV., ENERGY EFFICIENCY IN BUILDINGS: TRANSFORMING THE MARKET (2009), *available at* http://62.50.73.69/transformingthemarket.pdf.

42. *See* GEORGE MONBIOT, HEAT: HOW TO STOP THE PLANET FROM BURNING 178–82 (2006).

43. *See, e.g.*, JON CREYTS ET AL., MCKINSEY & CO., REDUCING U.S. GREENHOUSE GAS EMISSIONS: HOW MUCH AT WHAT COST? (2007), *available at* http://www.mckinsey.com/clientservice/ccsi/greenhousegas.asp (setting forth a cost-benefit analysis of the amount of expected emission reductions and associated costs).

of climate change in our future.[44] This could cause droughts, crop failures, forest fires, rising sea levels, and other disruptions.[45] While adaptation planning is beginning to receive attention, it lags far behind the other three mitigation strategies, perhaps because it is unpleasant to think about and disruptive to implement. For instance, while the amount of sea-level rise due to climate change is difficult to predict and will likely vary over time and by location,[46] coastal cities will need to address it through some combination of grade raisings and storm-surge barriers (such as those erected to protect Holland, Venice, and London) and even through land abandonment.[47] It is axiomatic that the longer it takes to reach a state of long-term carbon equilibrium, the more adaptation will be necessary.

Such carbon-management plans will necessarily evolve based on experience. They should incorporate monitoring and reporting of actual net carbon emissions reductions in order to track progress toward the allocated carbon sub-budget, and they should be updated on a defined schedule—perhaps every five years.

V. LESSONS FOR THE FUTURE

A transition to a balanced carbon budget approach from the current climate change framework that is based on setting target reductions in carbon emissions against a historic baseline represents a significant shift in policy. As a result, it is worth assessing existing climate change mitigation efforts in order to identify which measures are likely to be most effective. These lessons relate to: (1) the importance of choice, transparency, and advocacy in garnering public support and influencing private behavior; (2) the unique role of cities in addressing

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44. *See* PHYSICAL SCIENCE BASIS, *supra* note 8, at 822.

45. *See* IMPACTS, ADAPTATION AND VULNERABILITY, *supra* note 10, at 787–89 tbl.19.1.

46. *See* Alex Morales, *Oceans Rising Faster than UN Forecast, Scientists Say*, BLOOMBERG.COM, June 18, 2009, http://bloomberg.com/apps/news?pid=20601124&sid=afmw1nT6inhA (projecting a one-meter rise by 2100); SAN DIEGO FOUND., SAN DIEGO'S CHANGING CLIMATE: A REGIONAL WAKE-UP CALL 6 (Anahid Brakke ed., 2008) (projecting a twelve- to eighteen-inch rise in the San Diego region by 2050). *See also* IMPACTS, ADAPTATION AND VULNERABILITY, *supra* note 10, at 153–54 (discussing regional and local factors affecting sea-level rise).

47. Kristina Hill & Jonathan Barnett, *Design for Rising Sea Levels*, HARVARD DESIGN MAG., Fall 2007/Winter 2008, at 1, 5; Christopher Swope, *Local Warming*, GOVERNING, Dec. 2007, at 28, 29, *available at* http://www.governing.com/node/912/.

climate change; and (3) the importance of departing from established environmental ideologies.

A. Choice

The shift to a balanced carbon budget will likely be painful and unwelcome to many individuals, and it will continue to be resisted by free-market fundamentalists.[48] The major changes in economic and consumer behavior necessary to achieve a balanced carbon budget will be easier to accomplish if they are based on choice rather than on uniform mandates. However, it is irresponsible to advocate freedom of choice without providing individual actors with the information necessary to inform their choices, and without making clear that they will either suffer or enjoy the consequences of those choices.

The great power of markets is their ability to harness myriad individual choices and allocate resources efficiently.[49] But as the recent worldwide economic meltdown illustrates, markets do not always accurately account for long-term risk and are not perfectly self-correcting; they occasionally require major government intervention.[50] The global economic adjustment now underway was in part caused by a prolonged period of living on excessive credit—of borrowing from the future. In a similar fashion, we have borrowed the planet's carbon absorption capacity to finance our economic growth, and after more than a century, the debt is coming due.[51]

Correcting this market failure will require market actors to integrate the costs and consequences of carbon emissions into their decisions. A direct carbon tax, or an indirect assessment of fees to emit carbon through a cap-and-trade regime, would place an immediate economic cost on carbon emissions. This cost would in turn affect the price of every activity that

48. *See, e.g.*, Editorial, *McCain's Climate 'Market,'* WALL ST. J., May 13, 2008, at A16 (noting that "if 'the market' is your favored mechanism, . . . endorsement of a 'cap and trade' system is the worst choice for reducing greenhouse-gas emissions").

49. *See* Tom Gjelten, *Economic Crisis Stirs Free-Market Debate* (NPR radio broadcast June 23, 2009), *available at* http://www.npr.org/templates/story/story.php?storyId=105783108.

50. *See id.*

51. *See generally* SACHS, *supra* note 1, ch. 3 (explaining that the environment will not sustain maintenance of current rates of economic activity into the future); Heather Timmons, *Summers's Views Strike Chord in Asia*, BOSTON GLOBE, Apr. 19, 2007, at A13 (discussing the view that industrial countries have caused global warming, but developing countries will need to take action).

emits carbon-laden gases, from driving to buying manufactured products, and would create incentives to shift to reduced-carbon choices. But this element of choice is only the beginning of a solution if it is not linked to a long-term policy framework.

B. Transparency

The balanced carbon budget approach advocated by this Essay, based on a flexible system of choices instead of unpopular top-down mandates, requires an unprecedented level of monitoring, reporting, and adjustment toward the larger goal of carbon equilibrium.[52] This approach accomplishes two goals: (1) it informs private parties of the carbon consequences of their choices so they can adjust their behavior; and (2) it informs government of which strategies and measures have the greatest effect at the least cost, allowing government action to adjust accordingly.

Measurement and reporting practices have become much easier by the frictionless spread of information through the Internet, which creates rapid feedback loops.[53] Much technological innovation is now directed toward endowing inanimate objects with the electronic communication skills that most people already have. Such innovations include a "smart grid" to better handle electricity flows from multiple dissimilar sources, systems to allow the energy performance of buildings to be monitored and adjusted in real time, better transportation tolling and congestion management technology, and flood control structures that react to weather events.[54]

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52. In their book *Nudge*, Richard Thaler and Cass Sunstein (who has joined the Obama administration as Director of the White House Office of Information and Regulatory Affairs) have described the advantages of allowing choice within an overall policy framework, which they term "choice architecture," and using monitoring and reporting to reveal the consequences of these choices so they can be adjusted as required. THALER & SUNSTEIN, *supra* note 6.

53. Daniel C. Esty, *Environmental Protection in the Information Age*, 79 N.Y.U. L. REV. 115, 160–61 (2004) ("One of the most striking features of the Internet is its capacity for speedy and low-cost dissemination of information. Advances in environmental understanding thus can be transmitted immediately across the world. Hyperconnectivity changes the cost of establishing an appropriate technical foundation for environmental decisionmaking. Relevant information—details about on-the-ground conditions, answers to many scientific questions, and data on how others have dealt with particular issues—becomes much more readily available.").

54. *See* MITIGATION OF CLIMATE CHANGE, *supra* note 28, at 287; CREYTS, *supra* note 43, at 72.

C. *Advocacy*

While allowing choice and transparency might help build broad public support for the government intervention required to establish and implement a balanced carbon budget, the new energy and infrastructure facilities required to achieve a balanced carbon economy—from a smart grid to wind farms and rooftop solar panels—must also overcome local opposition.[55]

These aspects of a choice-based approach thus highlight the importance of nongovernmental organizations ("NGOs")—environmental advocacy groups, research universities, think tanks, and policy institutes—in helping to establish goals, monitor effectiveness, and disseminate information to guide the next round of policy adjustments. Such NGOs could also adopt, as a more explicit goal, addressing the problem of local opposition to development projects, often called "NIMBYism," by framing the issue of climate change so that the general public, as well as the immediate neighbors, can accept their share of the burden of solving it.[56]

D. *The Role of Cities*

Cities have a particular role to play in addressing climate change, and they will need support in order to fulfill this role effectively. Cities are the largest sources of carbon emissions because they concentrate human and economic activity.[57] However, cities also present the greatest opportunities for carbon reduction because their compactness enables more efficient use of building and transportation energy; as a result, urban residents have smaller per capita carbon footprints.[58] In addition, cities disproportionately host the research universities, business enterprises, think tanks, and policy institutes that are

55. *See* Mullane v. Cent. Hanover Bank & Trust Co., 339 U.S. 306, 313, 318–20 (1950) (setting forth the general constitutional test for adequate notice and public hearing for governmental decisions affecting property rights).

56. *See* Matthew Kiefer, *The Social Functions of NIMBYism*, HARVARD DESIGN MAG., Spring/Summer 2008, at 95.

57. J.C.R. Hunt et al., *Climate Change and Urban Areas: Research Dialogue in a Policy Framework*, 365 PHIL. TRANSACTIONS ROYAL SOC'Y A 2615, 2625 (2007).

58. David Dodman, *Blaming Cities for Climate Change? An Analysis of Urban Greenhouse Gas Emissions Inventories*, 21(1) ENV'T & URBANIZATION 185, 186, 198 (2009); David Owen, *Green Manhattan*, NEW YORKER, Oct. 18, 2004, at 111.

actively engaged in finding solutions.[59] This dynamic highlights the importance of cities, not only in adopting their own carbon-management plans to meet statewide carbon budgets, but also in advancing approaches to climate change more broadly.

But municipalities lack the ability to regulate power suppliers or to implement regional-transportation solutions. With limited taxation powers, they lack financial resources to implement carbon-management plans.[60] Accordingly, perhaps a portion of the revenue stream from selling carbon emission allocations can be directed to development and implementation of municipal carbon-management plans to meet the budget, in addition to using revenue for the broad national or global efforts to construct a planetary carbon model and for establishing measurement protocols leading to a carbon budget.

E. Environmental Orthodoxy

The environmental movement has been instrumental in spotlighting the importance of climate action. Yet, the effort to determine the most promising strategies to achieve a balanced carbon budget may require departures from some of its orthodoxies. For instance, the Smart Growth movement, which advocates accommodating population and economic growth in existing urbanized areas to reduce sprawl, has embraced climate change as a new impetus for creating more compact development patterns.[61] While this theory is based on the undeniable connection between land use and energy consumption,[62] the automobile-dependent sprawl that Smart Growth seeks to address took some sixty years to create. Reversing it will be an incremental and expensive process, given the cost and durability of buildings and infrastructure,[63] not to mention the reluc-

59. *See, e.g.*, SYNTHESIS REPORT, *supra* note 7, at 92–99 (listing authors and editors, largely from research institutions located within cities).

60. *See* Gerald E. Frug, *The City as a Legal Concept*, 93 HARV. L. REV. 1057, 1080–1120 (1980).

61. *See* Smart Growth America, The Link to Energy Security and Climate Change, http://www.smartgrowthamerica.org/factsheets/climate.pdf (last visited Aug. 5, 2009).

62. *Id.*

63. DONELLA MEADOWS, THE SUSTAINABILITY INST., LEVERAGE POINTS: PLACES TO INTERVENE IN A SYSTEM 7–8 (1999).

tance of suburban residents to abandon their subdivisions or permit them to be more densely developed.[64]

But suppose we can reverse sprawl in half the time it took to create it. Do we have thirty years to accomplish the resulting reductions? If the specific problem is carbon emissions, it may be faster and less expensive to develop low- or zero-emission vehicles, since cars have a much shorter useful life than houses. While several good reasons exist for reversing sprawl, and while the process should start now because it takes so long, we must also recognize that the climate-protection benefits are likely to be distant.[65]

Similarly, the environmental movement was instrumental in halting the spread of nuclear power due to the hazards of power-plant meltdowns and the difficulty of safely storing spent nuclear fuel.[66] Yet, nuclear plants produce electricity with virtually no carbon emissions. France derives some 76 percent of its electricity from nuclear power and maintains an exemplary safety record.[67]

The technology to build and operate safe nuclear plants has advanced in the last thirty years, as have the strategies for storing spent fuel.[68] While the hazards of nuclear power are not negligible, they may well be justified by the benefits, espe-

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64. Kaswan, *supra* note 30, at 291 ("[E]xisting residents who consciously chose a spacious suburban environment are likely to resist proposals for infill or for more compact development.").

65. *See, e.g.*, Phil McKenna, *Forget Curbing Suburban Sprawl: Building Denser Cities Would Do Little to Reduce CO_2 Emissions, a New NAS Report Concludes*, TECH. REV., Sept. 3, 2009, http://www.technologyreview.com/energy/23343/?nlid=2323&a=f; Locals Attack SB 375 as Inefficient Way to Go After Climate Change, Bill Fulton's Blog, http://www.cp-dr.com/node/2329 (May 27, 2009, 8:35 PST) (addressing California's recently adopted anti-sprawl legislation).

66. *See* Energy Info. Admin., Status of Potential New Commercial Nuclear Reactors in the United States (Feb. 19, 2009), http://www.eia.doe.gov/cneaf/nuclear/page/nuc_reactors/reactorcom.html (noting that 2007 saw the first application to build a new nuclear reactor in over three decades); Felicity Barringer, *Old Foes Soften to New Reactors*, N.Y. TIMES, May 15, 2005, http://www.nytimes.com/2005/05/15/national/15nuke.html (noting the safety concerns after Three Mile Island and the changing stance of the environmental movement towards nuclear power).

67. Int'l Atomic Energy Agency, Nuclear Share in Electricity Generation in 2008, http://www.iaea.org/cgi-bin/db.page.pl/pris.nucshare.htm (last visited Aug. 6, 2009).

68. World Nuclear Ass'n, Safety of Nuclear Power Reactors, http://www.world-nuclear.org/info/inf06.html (last visited Aug. 6, 2009). What has not advanced is public acceptance of the siting of the facility at Yucca Mountain in Nevada, and the Obama Administration has taken recent steps to withdraw it from consideration. Michael Hawthorne, *Obama Budget Puts Nuclear Waste on Hold*, L.A. TIMES, Mar. 11, 2009, http://articles.latimes.com/2009/mar/11/nation/na-nuclear-waste11.

cially in comparison to the alternative of carbon-based electric generation. Following the Precautionary Principle, the burden of proof, which environmental advocates successfully shifted to utility companies, may shift back again in the effort to reduce carbon emissions.[69]

CONCLUSION

We are in the midst of what one scientist has called "an uncontrolled geo-chemistry experiment."[70] It may take decades to definitively establish a "safe" level of human carbon emissions. In the meantime, adopting and implementing a balanced carbon budget will provide an insurance policy against human-induced disaster and will organize the response to climate change around a central policy framework, based on choice, transparency, and adjustment. This approach can harness ingenuity and the efficiency of the market, build public support by allowing actors to participate in choosing the required changes in their behavior, and reduce public anxiety by placing these costs, disruptions, and impacts in the context of a comprehensive approach to addressing a compelling social problem.

69. No less an environmentalist than Stewart Brand, founder of The Whole Earth Catalog, is now advocating nuclear power in order to address climate change. Stewart Brand, *Environmental Heresies*, TECH. REV., May 2005, at 60, 63.

70. Conversation with Jonas Peters, W.M. Keck Professor of Energy, Mass. Inst. of Tech., in Boston, Mass. (Feb. 26, 2009).