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Integrating Development into the Global Climate Regime

The past two decades have seen the creation and evolution of an international climate regime, with the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol as the main pillars (box 5.1). Kyoto set binding international limits on the greenhouse gas emissions of developed countries. It created a carbon market to drive private investment and lower the cost of emission reductions. And it prompted countries to prepare national climate-change strategies.

But the existing global regime has major limitations. It has failed to substantially curb emissions, which have increased by 25 percent since Kyoto was negotiated.[1] It has delivered only very limited support to developing countries. Its Clean Development Mechanism (CDM) has so far brought little transformational change in countries' overall development strategies (see chapter 6 on the strengths and weaknesses of the CDM). The Global Environment Facility has invested $2.7 billion in climate projects,[2] well short of the flows needed. The global regime has so far failed to spur countries to cooperate on research and development or to mobilize significant funding for the technology transfer and deployment needed for low-carbon development (see chapter 7). Aside from encouraging poor countries to prepare National Adaptation Programs of Action, it has delivered little concrete support for adaptation efforts. And the Adaptation Fund, slow to get started, falls far short of the projected needs (see chapter 6).

In 2007 the Bali Action Plan launched negotiations to achieve an "agreed outcome" during the UNFCCC 15th session in Copenhagen in 2009. These negotiations present an opportunity to strengthen the climate regime and address its shortcomings.

Building the climate regime: Transcending the tensions between climate and development[3]

If we are to meaningfully address climate change, there is no option but to integrate development concerns and climate change. The climate problem arises from the joint evolution of economic growth and greenhouse gas emissions. An effective regime must thus provide the incentives to reconsider trajectories of industrialization and unravel the ties that have bound development to carbon. However, for ethical and practical reasons, this rethinking must include meeting development aspirations and forging an equitable climate regime.

Until recently, climate change was not seen as an opportunity to rethink industrial

Key messages

A global problem on the scale of climate change requires international coordination. Nevertheless, implementation depends on actions within countries. Therefore, an effective international climate regime must integrate development concerns, breaking free of the environment-*versus*-equity dichotomy. A multitrack framework for climate action, with different goals or policies for developed countries and developing countries, may be one way to move forward; this framework would need to consider the process for defining and measuring success. The international climate regime will also need to support the integration of adaptation into development.

BOX 5.1 *The climate regime today*

The United Nations Framework Convention on Climate Change (UNFCCC), which was adopted in 1992 and entered into force in 1994, set an ultimate objective of stabilizing atmospheric concentrations of greenhouse gases at levels that would prevent "dangerous" human interference with the climate system. It divided countries into three main groups with different types of commitments:

Annex I parties include the industrial countries that were members of the OECD (Organisation for Economic Co-operation and Development) in 1992, plus countries with economies in transition (the EIT Parties), including the Russian Federation, the Baltic states, and several Central and Eastern European states. They commit to adopt climate-change policies and measures with the aim of reducing their greenhouse gas emissions to 1990 levels by the year 2000.

Annex II parties consist of the OECD members of Annex I, but not the EIT Parties. They are required to provide financial resources to enable developing countries to undertake emissions reduction activities under the UNFCCC and to help them adapt to adverse effects of climate change. In addition, they have to "take all practicable steps" to promote the development and transfer of environmentally friendly technologies to EIT parties and developing countries.

Non–Annex I parties are mostly developing countries. They undertake general obligations to formulate and implement national programs on mitigation and adaptation.

The ultimate decision-making body of the convention is its Conference of the Parties, which meets every year and reviews the implementation of the convention, adopts decisions to further develop the convention's rules, and negotiates substantive new commitments.

The Kyoto Protocol supplements and strengthens the convention. Adopted in 1997, it entered into force in February 2005, with 184 parties as of January 14, 2009.

At the heart of the protocol lie its legally binding emissions targets for Annex I parties, which have individual emissions targets, decided in Kyoto after intensive negotiation.

In addition to emissions targets for Annex I parties, the Kyoto Protocol contains a set of general commitments (mirroring those in the UNFCCC) that apply to all parties, such as

- Taking steps to improve the quality of emissions data,
- Mounting national mitigation and adaptation programs,
- Promoting environmentally friendly technology transfer,
- Cooperating in scientific research and international climate observation networks, and
- Supporting education, training, public awareness, and capacity-building initiatives.

The protocol broke new ground with three innovative mechanisms—joint implementation, the Clean Development Mechanism, and emissions trading[a]—designed to boost the cost-effectiveness of climate-change mitigation by opening ways for parties to cut emissions, or enhance carbon sinks, more cheaply abroad than at home.

The Bali Action Plan, adopted in 2007 by the parties to the UNFCCC, launched a comprehensive process to enable the full, effective, and sustained implementation of the convention through long-term cooperative action, now, up to, and beyond 2012 in order to reach an agreed outcome at the UNFCCC's 15th session in Copenhagen in December 2009.

The Bali Action Plan centered negotiations on four main building blocks—mitigation, adaptation, technology, and financing. Parties also agreed that the negotiations should address a shared vision for long-term cooperative action, including a global goal for emission reductions.

Source: Reproduced from UNFCCC 2005; UNFCCC decision 1/CP.13, http://unfccc.int/resource/docs/2007/cop13/eng/06a01.pdf (accessed July 6, 2009).

a. Parties with commitments under the Kyoto Protocol have accepted targets for limiting or reducing emissions. Joint implementation allows a country with a target to implement projects counted toward meeting their own target, but conducted in other countries that also have targets. The Clean Development Mechanism (CDM) allows a country with commitments to implement an emission-reduction project in developing countries that do not have targets. Emissions trading allows countries that have emission units to spare—emissions permitted them but not used—to sell this excess capacity to countries that are over their targets. (Adapted from http://unfccc.int/kyoto_protocol/mechanisms/items/1673.php, accessed August 5, 2009.)

development. The climate debate was isolated from mainstream decision making on financing, investment, technology, and institutional change. That time has substantially, if not entirely, passed. Awareness of climate change among leaders and publics has grown to the level that there is now readiness to integrate climate change into development decision making.

Turning this readiness into an effective climate regime requires simultaneously addressing multiple goals involving equity, climate, and social and economic development. It would be naïve to suggest that there are no tensions among these objectives. Indeed, the very perception of tradeoffs can prove a potent political barrier to integrating climate change and development. Differences in perceptions and conceptual frameworks across high-income and developing countries can and do get in the way of a meaningful discussion on how climate action can be integrated with development. Many of these tensions emerge along North-South lines.

To ensure a climate regime that speaks to development concerns, it is useful to identify and engage opposing perspectives and then seek to transcend them. This chapter discusses four points of tension between a climate perspective and a development perspective: environment and equity; burden sharing and opportunistic early action; a predictable climate outcome and an unpredictable development process; and conditionality in financing and ownership. These points of tension are characterizations using broad brush strokes to bring out the disagreements and their possible resolution, knowing that in practice individual country positions, in both the North and the South, are far more nuanced than the extremes described here. The second part of the chapter explores alternative approaches to integrating developing countries into the international architecture.

Mitigating climate change: Environment and equity

Since its beginning the climate regime has framed both equity and environmental goals as core elements. Over time, though, the articulation of these goals has turned their complementarities into opposition, deadlocking the progress of climate negotiations. Equity and environment have been increasingly perceived as competing ways of thinking about the problem, with countries arrayed behind these positions along predictable North-South lines.

For much of the past two decades, climate change has been construed mainly as an environmental problem. This perspective follows directly from the underlying science: greenhouse gases are accumulating in the atmosphere and causing climate impacts because of growing anthropogenic emissions, combined with limits to the ocean's and biosphere's ability to absorb greenhouse gases. In this perspective the problem is one of global collective action, and the instrument of choice is negotiated commitments for absolute reductions in emissions.

This strict focus on the environment forced the rise of a competing perspective, which construes climate change as essentially a problem of equity. Adherents to this position agree that there are environmental limits, but they see the problem as wealthy countries disproportionately occupying the finite ecological space available. In this perspective, allocation principles based on equity, such as those centered on per capita and historical emissions, should provide the basis of a fair climate regime.

Equity and environmental goals have thus become polar elements of the debate. High-income countries argue that newly industrializing countries are already large emitters and will contribute an increasing share of emissions in the future—hence the need for absolute emission reductions.[4] Industrializing and developing economies view a regime based on negotiated absolute reductions as locking in unequal emissions in perpetuity, a situation that is not viable for them. Concerns about equity have been heightened by evidence that emissions from many high-income countries have increased over the past two decades, since the initiation of climate negotiations. As the urgency of finding a solution has increased, many developing countries, particularly the large, rapidly industrializing countries, fear that attention and responsibility for mitigating emissions will be increasingly displaced onto them. The notion of "major emitters," including the large, rapidly industrializing countries, as primary drivers of the problem feeds this perception.

An effective and legitimate global climate regime will have to find a way around these opposing framings—and speak to both perspectives. To begin with, global negotiations need to be approached in a spirit of pluralism. Given the history of entrenched politics and the kernel of truth in each, neither the environmental nor the equity framing of the climate problem can, practically, be an absolute guide to negotiations, even though both are essential. Hybrid approaches seek to relocate discussions within a development frame and could usefully broaden the debate. One approach seeks to reformulate the problem around the right to develop rather than the right to emit and identifies country "responsibility" and "capacity" to act on climate change.[5] Another strand of thinking suggests the articulation of "sustainable development policies and measures" (meaning measures to place a country on a low-carbon trajectory that are fully compatible with domestic development priorities) by developing countries, combined with absolute reductions by high-income countries.[6] While the specifics of any proposal may be debated, the climate regime would be well served by a politics of pragmatism built around the careful integration of climate and development.

But for developing countries to believe that integrating climate and development is not a slippery slope toward ever greater mitigation responsibility being displaced onto them, it will be necessary to have the backstop of an equity principle in the global regime. One example might be a long-term goal of per capita emissions across countries converging to a band; this principle could serve as a moral compass and a means of ensuring that the regime does not lock in grossly unequal emission futures. Again, while the specifics may be debated, a legitimate climate regime will need anchoring in some form of equity principle.

Given the North's historical responsibility for stocks of greenhouse gases, already supported by strong statements in the framework convention, it is hard to imagine an effective global regime that is not led by early and strong mitigation action by the developed world. The combination of early action by the North, a robust equity principle, and a spirit of pluralism in negotiations could provide the basis for transcending the environment-equity dichotomy that has plagued global climate negotiations.

Burden sharing and opportunistic early action

The environmental and equity constructions of the climate challenge share a common assumption that the challenge is a problem of burden sharing. The burden sharing language suggests that climate mitigation is going to impose considerable costs on national economies. Because current infrastructure and economic production are built on the assumption of costless carbon, building economies and societies around costly carbon will impose considerable adjustment costs. The difficult North-South politics around climate is closely tied to the burden sharing assumption, because environment and equity constructions of the problem imply very different ways of sharing a burden and therefore different political costs.

Recognizing how burden sharing contributes to entrenched politics, advocates for early climate mitigation have sought to develop a counternarrative of climate mitigation as an opportunity to be seized rather than a burden to be shared. They point out that the history of environmental regulation is littered with examples of responses to regulation that have proved less costly than feared—acid rain and ozone depletion are two well-known examples.[7] Even if climate mitigation imposes costs in the aggregate, there are relative advantages to first movers in mitigation technologies. First movers will be well placed to seize new markets that emerge as carbon is priced. Many climate-mitigation opportunities—notably energy efficiency—can be harvested at negative economic cost and bring other co-benefits for development. And in the medium term, moving first allows societies to cultivate the positive feedbacks among institutions, markets, and technology as their economies are reoriented around a low-carbon future. In its strongest variant the opportunity narrative is one of seizing advantage by moving first on climate mitigation, independent of what other countries do.

But it is important not to overplay this narrative. Conceptually the tightness of the weave between the climate and industrial development suggests that adjustment costs are likely to be substantial—and that past comparisons such as acid rain and ozone depletion are of limited relevance. Neither the stock of industrial capital built around costless carbon nor the dependence on endowments of fossil fuels can simply be wished away. Skeptics will note that, so far, the narrative of climate opportunity has not been matched by concrete actions by any major high-income country to enable developing countries to realize this opportunity.

Moreover, even if countries believe the language of opportunity, they are likely to act strategically by maintaining a public stance based on burden sharing to win a better negotiating deal, even while privately organizing to seize available opportunities. So, opportunity-seizing is unlikely to entirely dethrone burden sharing as a dominant narrative in the short run—it provides only a limited opening to change the entrenched politics of climate change.

It is important, however, that this limited opening be seized. The prospect of a silver lining of economic opportunity to the climate cloud could tip the political balance toward getting started with the hard task of turning economies and societies toward a low-carbon future. Getting started with no prospect of an upside is a much harder sell. And starting is important, because it creates constituencies with a stake in a low-carbon future, begins the process of experimentation, and increases the costs to others of being left behind, thus generating a pull effect. That the language of opportunity seizing is not watertight does not negate its potential to counter burden sharing as the prominent construct in the climate debate (box 5.2).

Predictable climate outcome and unpredictable development process

Burden sharing is linked to the environment framing of the climate problem, from which the need emerges to set absolute reduction targets to avoid catastrophic climate change. Drawing on the recommendations of the Intergovernmental Panel on Climate Change (IPCC), some countries and advocates have urged a global goal of restricting global temperature rise to not more than 2°C, which will require reducing global emissions by at least 50 percent (the lower bound of the IPCC's range of 50–85 percent) by 2050 from their 1990 levels.[8] In response several high-income countries have submitted proposed national reduction targets (for 2050 and in some cases for interim years).[9] The underlying idea is to measure and benchmark progress toward meeting the climate challenge.

A global goal is particularly useful as a way to assess the commitment offers of the high-income world against the magnitude of the challenge. But, as discussed in chapter 4, simple arithmetic suggests that a global goal also carries implications for developing countries; the gap in reductions between the global goal and the sum of high-income country targets will have to be met by the developing world. Several developing countries therefore resist this approach as a back door into forcing commitments by the developing world or insist on a simultaneous discussion of an allocation framework.[10] This resistance stems less from opposition to the global goal and more from a sense that the language of predictability will prove a slippery slope toward translating all actions into absolute emission reductions, leading to an implicit cap on developing-country emissions.

The climate challenge looks quite different through a development lens. Building on a rich and complex intellectual history, a recent strand of development thinking focuses on institutions and institutional inertia in development (chapter 8). In this perspective formal "rules of the game" and informal norms, including those embedded in culture, are important determinants of economic incentives, institutional transformation, technological innovation, and social change. Politics is central to this process, as different actors organize to change institutions and transform incentives. Also central are the mental maps of what actors can bring to their engagement with development processes. Three key ideas are relevant here. First, development is a process of change, largely driven from below. Second, history and the past patterns of institutions matter a great deal, so common templates are of only limited use—one size does not fit all. Third, this characterization of change applies equally to high-income countries, even though the challenge of imperfect and incomplete institutions appears less daunting, and top-down policy and price signals are considered to be the main drivers of change.

In this perspective the task of low-carbon development in developing countries is a long-term process, one less amenable to being driven from above by targets and timetables than in high-income countries. Instead, changes in the direction of low-carbon development can be brought about only by internalizing this objective in the larger development processes in which bureaucracies, entrepreneurs, civil society, and citizens are already engaged. In other words, climate has to be integrated with development. An example of this approach might be rethinking urban planning in a low-carbon future, ensuring the colocation of work and residence to reduce the need for transport, designing more sustainable buildings, and devising solutions to public transport (see chapter 4). This contrasts with a target-led short-run approach, which might emphasize more fuel-efficient cars within existing urban infrastructures.

As highlighted in chapter 4, both approaches are necessary, one to yield results in the short run and the other to permit the necessary long-run transformation. The

BOX 5.2 Some proposals for burden sharing

Contraction and convergence
The contraction-and-convergence approach assigns every human being an equal entitlement to greenhouse gas emissions. All countries would thus move toward the same per capita emissions. Total emissions would contract over time, and per capita emissions would converge on a single figure. The actual convergence value, the path toward convergence, and the time when it is to be reached would all be negotiable.

Greenhouse Development Rights
The Greenhouse Development Rights Framework argues that those struggling against poverty should not be expected to focus their limited resources on averting climate change. Instead it argues for wealthier countries with greater capacity to pay and more responsibility for the existing stock of emissions to take on the bulk of the costs of a global mitigation and adaptation program.

The novelty of the Greenhouse Development Rights approach is that it defines and calculates national obligations on the basis of individual rather than national income. A country's capacity (resources to pay without sacrificing necessities) and responsibility (contribution to the climate problem) are thus determined by the amount of national income or emissions above a "development threshold." This is estimated at about $20 a person a day ($7,500 a person a year), with emissions assumed proportional to income. The index of capacity and responsibility under the Greenhouse Development Rights Framework would assign to the United States 29 percent of the global emission reductions needed by 2020 for 2°C stabilization, followed by the European Union (23 percent) and China (10 percent). India's share of global emission reductions would be around 1 percent.

Brazil proposal: historical responsibility
In 1997, in the negotiations leading to the Kyoto Protocol, the government of Brazil proposed that "historical responsibility" be used as the basis for apportioning the burden of mitigation among Annex I countries (meaning the countries with firm targets). The proposal sought to address "the relationship between the emissions of greenhouse gases by Parties over a period of time and the effect of such emissions in terms of climate change, as measured by the increase in global mean surface temperature." The notable feature of the proposal was the method used to distribute emission reduction burdens among countries, according to which an Annex I country's emission targets should be set on the basis of that country's relative responsibility for the global temperature rise.

The proposal included a "policy maker model" for determining emission targets for countries and suggested the need for an "agreed climate-change model" for estimating a country's contribution to global temperature increase.

Carbon budget
A research group at the Chinese Academy of Social Sciences argues that

- Greenhouse gas emission rights are a human right that ensures survival and development. Equality means ensuring equality among individuals, not among nations.
- The crux of promoting equality between individuals is to ensure the rights of the current generation. Controlling population growth is a policy option to promote sustainable development and to slow climate change.
- Given the wealth accumulated during development, which was accompanied by greenhouse gas emissions, equality today includes equity acquired in historical, current, and future development.
- Giving priority to basic needs means that the allocation of emission entitlements should reflect differences in natural environments.

If only CO_2 emissions from fossil fuels are considered and emissions peak in 2015 and fall to 50 percent of 2005 levels by 2050, the annual per capita carbon budget for 1900 to 2050 would 2.33 metric tons of CO_2. Initial carbon budget allocations for each country should be proportional to base-year population, with adjustments for natural factors such as climate, geography, and natural resources.

Developing nations, despite often being historically under budget and therefore having the right to grow and to create emissions, have no choice but to transfer their carbon budgets to developed nations in order to cover the historical excesses of developed nations and ensure basic future needs.

This historical debt amounts to some 460 gigatons of CO_2. At the current cost of $13 a ton, the value of this debt would be $59 trillion—substantially more than is currently provided to developing countries in financial assistance to combat climate change.

Continued high per capita emissions in high-income countries could partly be offset through the carbon market. But progressive carbon taxes are likely to be necessary, with the excess carried over to the next round of commitments.

Sources: Contraction and convergence: Meyer 2001. Greenhouse development rights: Baer, Athanasiou, and Kartha 2007. Brazil: submission from the government of Brazil to the UNFCCC in 1997 (http://unfccc.int/cop3/resource/docs/1997/agbm/misc01a3.htm, accessed July 7, 2009). Carbon budget: reproduced from Jiahua and Ying 2008.

two perspectives are, thus, complementary. A climate-oriented perspective can throw up a series of short-term policy prescriptions that can, in substantial measure, be implemented across countries with minimal adjustment while also yielding development benefits. Many of them are in the realm of energy efficiency, such as improved building codes, appliance standards, and the like.[11] And these approaches can be embedded in a longer-term process aimed at rethinking development through a climate lens.

But concern with the short term and the predictable should not crowd out or exclude longer-term but more fundamental transformations toward low-carbon development.

And there are risks that overly enthusiastic benchmarking of developing-country efforts to a long-term global target will do just that. As described above, many transformational measures are not subject to top-down planning and so are not subject to prediction and easy measurement. Indeed, an insistence on measurement and predictability will encourage only modest measures to minimize risks of noncompliance. In addition, any hint of an implicit target reached by subtracting high-income-country emissions from a global target encourages strategic gaming; under these conditions, countries have an incentive to persuade the international community that little can be done at home and only at high cost.

Reconciling these two perspectives may require a nested two-track approach for the short-to-medium term, at least until 2020. Consonant with the UNFCCC principle of "common but differentiated responsibility," high-income countries could agree to prioritize predictability of action aimed at carbon mitigation, to provide some assurance that the world is on track to meet the climate challenge. Here, short- and medium-term targets, for 2020 and 2030, are as significant as a target for 2050, because carbon reductions are more useful now than later and because they can win the confidence of the developing world. The developing countries could follow a second track, as discussed later in this chapter, that sets priorities for reorienting their economies and societies to low-carbon development.

These approaches, it should be clear, need not and should not compromise living standards—they should instead aggressively explore the co-benefits of development for climate. Nested within this longer-term objective, developing countries could agree to short-term "best-practice" measures—notably for energy efficiency—that bring both developmental and climate benefits. Agreeing to aggressively pursue these measures would provide some reassurance that some predictable climate gains will be realized in the short term.

The problem of financing—conditionality and ownership

The foregoing tensions are closely tied to the problematic issue of financing climate actions. There is broad agreement that high-income countries will transfer some funds to the developing world to assist specifically with adaptation—and provide separate funding for mitigation. But questions remain about how much financing will be available, its source, how its expenditure will be controlled, and on what basis it will be monitored; those questions are discussed here.

Governments of high-income countries are anxious that any funds provided be well targeted to climate mitigation or adaptation and produce real and measurable reductions (in emissions or vulnerability). To this end they envision having oversight of these funds, particularly in the current tight fiscal climate, where domestic constituencies may have little appetite for sending money overseas. This is particularly true for mitigation finance. Indeed, many high-income countries see public funds as playing a limited role in supporting climate financing in the developing world, instead envisioning that a greater proportion of funds be harnessed through market mechanisms.

Developing countries envision these funds entirely differently, as paying to help them adjust to and contribute to the mitigation of a problem not of their making. As a result, they eschew any overtones of aid and strongly resist any mechanisms of conditionality. To the contrary, they envision the use of these funds as guided by recipient-country priorities.

Elements in both positions appear reasonable. There are good arguments for not considering transfers of climate-related funds within an aid umbrella because of high-income-country responsibility for a substantial part of the climate problem. But it would appear politically difficult for high-income countries to sign a blank check without some mechanism of accountability for the funds. One way forward might be to focus on what the past teaches about conditionality as a tool.

Developing-country positions in the climate debate are, in part, shaped by the fraught history of conditionality in development debates. Civil society and other actors came to see conditionality as an instrument that undercuts democracy and forced through unpopular reforms. Because the conditions imposed did not prove particularly effective in helping governments undertake politically difficult reforms, conditionality gave way within a decade to the almost opposite concept of borrower "ownership" of a reform agenda as a precondition for policy reform loans.[12] The lesson for climate change appears to be that—even purely on pragmatic grounds, putting aside principles connected with responsibility for the problem—conditionality is simply not an effective tool for getting governments to take measures with little domestic support.

Fortunately, there is a more productive way to conceptualize how climate funds might be used. A first step requires redirecting attention from implementing actions predetermined by a donor to organizing funding around a process to encourage recipient-country development and ownership of a low-carbon development agenda. This is similar to the poverty reduction strategy approach discussed in chapter 6, whereby donors align around a strategy designed and owned by the recipient government. Such an approach would place the emphasis on the governance mechanism for fund providers and fund recipients to collectively scrutinize and oversee climate finance.

A second step is for mitigation financing to support both low-carbon development and well-specified mitigation actions in developing countries. The concrete actions should be collectively agreed on by those providing and those receiving funds as serving the dual functions of climate mitigation and development gains. As discussed earlier, many energy-efficiency measures would be good candidates for easy agreement.

Coming to agreement on supporting low-carbon development is more amorphous and challenging. But the lesson from conditionality is that the path for low-carbon development should be developed through a process that builds considerable recipient-country ownership. The efforts of a number of governments, such as Mexico and South Africa among others, to develop a long-term carbon mitigation strategy as a basis for identifying concrete actions and seeking international support are one interesting model. The rest of this chapter discusses avenues for developing these alternative approaches.

Options for integrating developing-country actions into the global architecture

Developing countries need to be persuaded that there is a feasible route to integrating climate change and development if they are to rapidly start the transition to a low-carbon development path. If the international climate regime is to promote stronger action by developing countries, it must incorporate new approaches appropriate to their circumstances. Any mitigation effort required for the developing countries must be grounded on "a clear understanding of the economic and governance context for their development choices and their overriding development priorities."[13] The future regime must be designed in a way that recognizes their efforts to reduce their emissions while achieving their development objectives.

So far, the primary vehicle for mitigation action within the regime has been economywide emission targets pegged to historical base-year emission levels, as in the Kyoto Protocol. Such an output-based approach (focused on the emission "output") is driven by the core objective of achieving and maintaining a tolerable level of greenhouse gas concentrations in the atmosphere.[14] Fixed economywide emission targets have two advantages. They provide certainty about the environmental outcome (assuming they are met). And they allow countries considerable flexibility to choose the most suitable and cost-effective means of implementation. This target-driven approach remains appropriate for developed countries.

But such a climate-centric approach is perceived as problematic for developing countries, at least at this stage of the climate regime. Many developing countries see a cap on total emissions as a cap on economic growth. Having demonstrated their competitive success, the countries fear that the climate agenda will hold them back. These concerns spring from the fact that the principal driving forces of emissions growth in developing countries are the development imperatives of energy and economic growth. And as a practical matter, setting and adhering to an economywide emission target requires the ability to accurately measure and reliably project emissions across a country's economy, a capacity that many developing countries now lack.

So engaging developing countries more fully in the climate regime may require alternative approaches deemed more appropriate to their circumstances. These approaches could build on the types of actions and strategies already being developed or implemented at the national level. Unlike emission targets, these actions can generally be characterized as "policy-based," centering on activities that generate emissions, rather than on emissions themselves. To achieve energy efficiency, a country could introduce a standard or incentive to shift behavior or technology. Lower greenhouse gas emissions would be one outcome, but the policy also would produce benefits more closely related to a country's core development objectives, such as greater energy affordability and access. Depending on their circumstances, countries could put forward different sets of policies or actions that address such development objectives as economic growth, energy security, and improved mobility while also delivering the co-benefit of reduced emissions.

A key question, however, is how to reconcile this approach with the urgency imparted in chapter 4—the notion that unless mitigation is immediate and global it will not be possible to maintain warming anywhere close to 2°C. New analysis, presented below, on multitrack frameworks and the impact of advance commitments suggests that a flexible approach could be effective.

An integrated multitrack climate framework

To better integrate development concerns into climate change efforts, the global climate regime must become more flexible and accommodate different national circumstances and strategies, especially for mitigation efforts. The Kyoto Protocol establishes a single type of mitigation commitment—a binding, absolute, economywide limit on emissions. This is sound from the perspectives of environmental effectiveness and economic efficiency, but as a political and practical matter it is an unlikely avenue for developing countries at this stage.

A more flexible regime integrating different approaches by different countries can be conceptualized as an "integrated multi-track" framework.[15] Many international regimes have the characteristics of such an approach. For example, the multilateral trade regime includes agreements accepted by all World Trade Organization members and plurilateral agreements among smaller groupings of members. Europe's Long-Range Transboundary Air Pollution regime and the International Convention for the Prevention of Pollution from Ships include core agreements setting forth common terms and annexes establishing differential obligations. Experiences within these arenas provide valuable lessons for climate policy makers, but the climate regime requires a distinct architecture matching a unique set of political and policy imperatives.

In broad terms, a multitrack climate regime could include at a minimum two distinct mitigation tracks:

- *Target track*. For developed countries and other countries that may be prepared to undertake such commitments, the target track would establish binding, absolute, economywide emission targets succeeding those established under the Kyoto Protocol's first commitment period. Countries with such targets would have full access to the agreement's international emissions-trading mechanisms.
- *Policy-based track*. On this track, other countries would agree to undertake nationally driven policies and actions that would have the effect of reducing emissions or emissions growth. Such policies could be sector based or economywide and could include, for example, energy-efficiency standards, renewable energy targets, fiscal measures, and land-use policies. Countries could propose individual policies or put forward comprehensive low-carbon development strategies identifying priority sectors and policies and the support needed for their implementation.

Recent modeling of such hybrid frameworks suggests that multitrack approaches score well on environmental effectiveness and equity and that the efficiency losses may be a reasonable tradeoff to achieve broad participation in policies that put countries collectively on track to greenhouse

BOX 5.3 *Multitrack approaches score well on effectiveness and equity*

Recent modeling by Battelle Memorial Institute's Joint Global Change Research Institute, in collaboration with the Pew Center on Global Climate Change, indicates that an "integrated multitrack" climate framework, in which developed countries undertake economywide emission targets and developing countries undertake nontarget policies, can produce global emission reductions by midcentury consistent with achieving atmospheric greenhouse gas concentrations of 450 ppm CO_2 by 2100.[a]

In the global policy scenarios, developed regions reduce their emissions 20 percent below 2005 levels by 2020, and 80 percent below by 2050; developing regions adopt a range of policies in the energy, transportation, industry, and buildings sectors, such as carbon-intensity goals, efficiency standards, and renewable energy targets. The specific policies, and their stringency, vary among the developing-country regions. "Policy-based crediting" awards developing regions tradable emission credits for a portion of the reductions their policies achieve (starting at 50 percent in 2020 and declining to zero in 2050).

The analysis shows global emission reductions in 2050 nearly as steep as those under an idealized "efficient" 450 ppm pathway in which full global emissions trading achieves reductions wherever and whenever they are least expensive. Globally, costs through 2050 are higher than in the efficient case, emphasizing the importance of moving toward full emissions coverage and full global trading by midcentury. But even with this loss in efficiency, costs remain below 2 percent of global gross domestic product (GDP) in 2050. Further, the policy-based crediting approach redistributes costs globally so that costs as a share of GDP are significantly lower in developing regions. In the early years, revenue from the sale of emission credits exceeds domestic mitigation costs in some developing regions, producing net economic gains.

Source: Calvin and others 2009.

a. The model does not specifically look at temperature increases. However 450 ppm CO_2 corresponds to concentrations of about 550 ppm CO_2e (a measure of all greenhouse gases, not just CO_2), hence possible temperature increases of around 3°C. At the time this report went to press, this exercise had not been conducted for 450 ppm CO_2e, which corresponds to a 40 to 50 percent probability of warming remaining below 2°C.

gas concentrations of 450 parts per million (ppm) CO_2 or 550 ppm of CO_2e (box 5.3).

Other modeling has also convincingly shown that a multitrack framework can be very effective if it provides some certainty as to when a country may commit to a binding agreement.[16] This, in fact, reduces the cost for any country of joining a binding agreement in the future because it spreads the transition over a longer period of time and investors can factor eventual policy changes into their investment choices, a process that reduces the amount of stranded assets or expensive retrofits a country can be left with.

In addition to the mitigation tracks, a comprehensive agreement would need to include

- An adaptation track to assist vulnerable countries with adaptation planning and implementation
- Cross-cutting enabling elements on technology, finance, and capacity-building support to developing countries
- Means to measure, report, and verify mitigation actions and support for the mitigation actions of developing countries, as specified under the Bali Action Plan.

Chapter 4 showed that it would be almost impossible to remain close to 2°C warming with delayed participation of developing countries. Instead multitrack frameworks permit early action but emphasize win-win options. And the models and the approaches discussed here suggest that multitrack approaches and forward-looking, predictable policies are worthwhile approaches to reconciling the need for urgent action and the priority that must be granted to development and poverty alleviation.

A policy-based mitigation track

To recognize and advance developing-country mitigation efforts, the major new element needed in the climate regime is a new category of mitigation action that is broad and supple enough to incorporate a wide variety of actions. Many developing countries have begun to identify existing and potential policies and actions at the national level that, while not driven exclusively or primarily by climate-change concerns, contribute to climate-mitigation efforts. As these policies and actions arise within national contexts, they inherently reflect a country's national circumstances and its development objectives and priorities. Indeed many of these policies are driven by development objectives such as energy access and security, better air quality, improved transportation services, and sustainable forestry, with mitigation an incidental co-benefit.

A mechanism that allows the integration of such nationally driven policies into the international framework offers four advantages to developing countries. First, it enables developing countries to contribute to the climate effort in ways that, by their own determination, are compatible with their development agendas. Second, it allows each country to come forward with a nationally defined package tailored to its circumstances, capabilities, and mitigation potential. Third, if it is coupled with a robust support mechanism, policies can be scaled or tiered to provide for stronger action on the provision of stronger support. Fourth, while providing a clear pathway for stronger mitigation efforts by developing countries, it does not bind them to quantified emission limits, which they perceive as undue constraints on their growth and development.

The case for a policy-based track has been advanced in the academic literature in different guises. One formulation, called "sustainable development policies and measures" (SD-PAMs), envisions voluntary pledges by developing countries.[17] Another proposal describes "policy-based commitments" in which the policy content might be identical to that under an SD-PAMs approach but would be reflected in the international framework as a commitment rather than a voluntary action.[18] Since the adoption of the Bali Action Plan, governments have put forward proposals addressing various aspects of how a policy-based approach could be made operational in a future climate agreement.[19]

In fashioning a new policy-based track as part of an evolving international climate framework, governments would need to consider several interrelated issues, including

- The process for countries to bring forward policies and actions and have them reflected in the international framework
- The legal character of these policies and actions
- The links to other mechanisms providing incentives and support for their implementation
- The standards and mechanisms for measuring, reporting, and verifying the policies and actions and the support for them.

Process for introducing policy actions. For country policy actions to be recognized within the international framework, governments would need to establish a process to bring them forward and, possibly, to have other parties consider and accept them. Within the negotiations, some parties have proposed the establishment of a "registry" for countries to record nationally appropriate mitigation actions they plan or propose to undertake.[20]

One critical issue is whether the process of bringing actions forward occurs in the course of negotiating a new agreement or is an outcome of those negotiations. The latter may be preferable for most developing countries. In this scenario a new agreement would establish binding emission targets for developed countries, mechanisms to support developing-country mitigation and adaptation efforts, and a process for developing countries to then define their mitigation actions. But developed countries may be reluctant to enter into binding emission targets unless the major developing countries are prepared to indicate at the same time the actions they will undertake. In that case the process of specifying those actions could be structured as part of the negotiating process, with the aim of arriving at a comprehensive agreement integrating binding targets for developed countries and specified policy actions for developing countries.

In either case, parties also need to consider whether the process should be completely open-ended, with countries free to propose any type of policy or action, or circumscribed in some way. One option proposed in the negotiations is a menu, or "tool box," of mitigation actions for developing countries to choose from.[21] The menu could identify broad categories of action, with parties invited to put forward detailed policies or action plans within the categories they choose. For consistency or comparability it may be useful to establish some form of template for countries to follow in describing their mitigation actions.

Another important consideration is quantifying the expected emission impacts of mitigation actions. Although countries participating in a policy-based track would not be committing to specific emission outcomes, other parties will want to know what impact their actions are likely to have on their future emissions. At a minimum countries should be prepared to offer such projections. Depending on the type of process established, emission projections also could be prepared or verified by an intergovernmental body or an independent third party.

Legal character. The Bali Action Plan distinguishes between "nationally appropriate mitigation commitments or actions" by developed countries and "nationally appropriate mitigation actions" by developing countries, implying that the actions of developing countries are not to take the form of legally binding commitments. Indeed, proposals put forward by developing countries in the post-Bali negotiations, including proposals for a registry of developing-country actions, emphasize the voluntary nature of these actions.

But the Bali Action Plan does not expressly preclude commitments by developing countries, contrary to the 1995 Berlin Mandate that framed the negotiations that led to the Kyoto Protocol. In the current round of negotiations some developed countries have taken the position that actions by some developing-countries should be binding.[22] Developing countries, however, have been reluctant to take on binding commitments, at least at this stage.

Links to support. Robust efforts by developing countries will be feasible only with stronger international support. Indeed, under the Bali Action Plan, the mitigation actions of developing countries are to be "supported and enabled by technology, financing, and capacity building." Potential mechanisms to generate such support are discussed below. If parties were to establish a policy-based mitigation track for developing countries, a related question is how actions under that track would be linked to specific flows of support.

Any process to enable countries to bring forward proposed actions could, in addition, identify means and levels of support for those actions. For example, in entering a proposed action in a mitigation-action registry, a country could indicate the type and level of support needed to implement the action. Or a country might specify the level of effort it is prepared to deliver on its own, and a higher level of effort it would be prepared to undertake with support. Or recording an action in the registry could initiate a review by a designated body, using agreed criteria, to evaluate the need for support, taking into account a country's circumstances and capacities. All of these approaches could lead to a determination of support commensurate with the proposed action.

Measurement, reporting, and verification. Parties agreed in Bali that the mitigation efforts of developed and developing countries—as well as the support for developing-country efforts—are to be "measurable, reportable, and verifiable" (MRV). Effective approaches to MRV can establish and maintain parties' confidence in one another's respective efforts and in the overall regime. To be workable, MRV terms and mechanisms must balance the need for transparency and accountability against the parties' traditional concerns about sovereignty.

Reporting requirements for developing countries under the existing regime are fairly minimal—national "communications" (including emission inventories) are submitted infrequently and are not subject to review. In a future agreement the MRV of developing-country actions on a policy-based mitigation track would likely require a more rigorous approach. Parties first must consider what actions are subject to measurement and verification. Some developing countries have taken the view that MRV should apply only to actions for which they are receiving support. A second issue is whether verification is performed by the country, an international body, or a third party. In some international regimes parties verify their own actions under national systems that must conform to international guidelines. In others expert teams review parties' submissions (as for national communications and emission inventories submitted by developed countries under the UNFCCC and the Kyoto Protocol).

Third is the metrics to be employed, regardless of the means of verification. One rationale for a policy-based track is that it allows parties to pursue the types of action most appropriate to their circumstances and development objectives. This diversity presents challenges for MRV, however, because different metrics are needed to measure and verify different types of actions (efficiency standards, renewable energy targets, carbon levies). How MRV is structured will therefore depend very heavily on how the actions are defined. In turn, the need for actions to be measurable and verifiable could strongly influence the way parties choose to define them. Somehow bounding the types of actions allowable in a policy-based track—say, by establishing a menu for parties to choose from—could make MRV more manageable.

Measurement and verification of developed-country support will likewise depend heavily on the specific types and mechanisms of support. If a new agreement were to recognize support provided through bilateral channels, criteria would be needed to determine what flows are "climate related" and "new and additional." As a general matter, support generated through a multilateral instrument, such as an international carbon levy or an auction of international emission allowances, would be more readily verifiable.

Support for developing-country mitigation efforts

The ability of developing countries to develop and effectively implement mitigation actions will depend in part on the availability of adequate and predictable support from the international community. General areas of support include finance, technology, and capacity building. These could include analyzing mitigation potentials to identify opportunities to reduce greenhouse gases with the lowest cost and highest co-benefits, developing and implementing greenhouse gas mitigation policies, disseminating and deploying the best available technologies, and measuring and verifying mitigation actions and their associated sustainable development benefits.

Adequate support will require a range of mechanisms to generate and channel public resources and to do so in a way that leverages private investment, which under any scenario will be the majority of flows available for a low-carbon transition (see chapter 6). The climate regime has two broad forms of support—public finance and market-based mechanisms—and both must be substantially scaled up in a future agreement.

Public finance

A new multilateral effort must scale up public finance in support of developing countries. Among the key issues are funding sources, funding criteria, funding instruments, links to private finance, and managing and governing any new funding mechanisms (all discussed extensively in chapter 6). This section highlights a few findings.

Most of the funds under the climate regime have relied on pledging by donor countries, resulting in inadequate and unpredictable flows. Several proposals now under discussion could produce more reliable funding streams. These include funding commitments based on agreed assessment criteria, a levy on international aviation or other greenhouse gas–generating activities, or an auction of a portion of developed countries' international emission allowances. Another option—pressed by developing countries at the UN Climate Change Conference in Poznań, Poland, in December 2008—is an extension of the existing levy on CDM transactions to the Kyoto Protocol's other market-based flexibility mechanisms (international emissions trading and joint implementation).[23]

Any new fund could deploy an array of funding instruments, including grants, concessional loans, loan guarantees or other risk mitigation instruments, depending on the types of activity to be supported. For technology the options include payments for access to and use of intellectual property and the associated technological know-how. Important criteria in selecting activities for funding could include the projected emission reduction per dollar of investment, a project's contribution to a host country's sustainable development objectives, or its ability to leverage carbon finance or other private investment.

Market-based mechanisms

The Kyoto Protocol's Clean Development Mechanism has generated substantial flows supporting clean energy and other greenhouse gas-reducing projects in developing countries. While the CDM has had many successes, experience has also highlighted many concerns and areas for potential improvement (chapter 6). Beyond the reform of the original CDM model, however, parties have also begun to consider alternative approaches to emission crediting to provide incentives for investment and emission reduction on a broader scale.

As initially conceived and currently operating, the CDM generates emission credits from individual projects proposed and certified case by case. In the view of many, this project-based approach excludes many strategies with greater mitigation potential and imposes high transaction costs and administrative burdens, significantly limiting the CDM's potential to transform long-term emission trends. In an initial attempt to address these concerns, parties have authorized a "programmatic" CDM, which allows an aggregation of multiple activities over space and time as a single project. But emission reductions are still measured on the basis of discrete activities.

Alternative models now under discussion include sectoral or policy-based crediting. By allowing the generation of credits on the basis of policies or other broad programs, such approaches would help drive and support larger-scale emission-reduction efforts. Under a sectoral approach, for instance, emissions would be measured across an entire sector, and a country could earn credits for any reductions below an agreed emissions baseline. (This approach is sometimes described as "no-lose sectoral crediting," because a country faces no consequences if emissions rise above the agreed baseline.) The baseline could be set at business as usual, rewarding any deviation from projected emission levels. Or it could be set below business as usual, requiring that a country undertake some reductions on its own before qualifying for credits. Given the uncertainties in any projection of future emissions, however, the determination of business as usual is somewhat subjective and potentially quite contentious.

Under policy-based crediting a country could earn credits for verifiable reductions achieved by implementing mitigation policies recognized within the climate regime or by deploying technology action. This approach fits well with the notion of a policy-based mitigation track, providing a market-based incentive for countries to develop, put forward, and implement mitigation policies aligned with their development objectives. Methodologies could be established to quantify the reductions from different types of policy approaches. Crediting countries for all the reductions generated by their policy actions could cause an excessive supply of credits; developed countries might also object on the grounds that developing countries should bear some of the cost of their policy actions. These concerns could be addressed by issuing credits only after a certain reduction has been achieved or by discounting credits (say, by issuing one ton of credit for every two tons reduced).

Promoting international efforts to integrate adaptation into climate-smart development

Stronger international support for adaptation is a matter of need, because climate impacts are already being felt and because the poor who contribute least to the problem face the gravest risks. But adaptation efforts must extend well beyond the climate framework. As chapters 2 and 3 suggest, adaptation concerns and priorities must be integrated across the full breadth of economic and development planning and decision making, both national and international. The role of the international climate regime in particular lies with catalyzing international support and facilitating national adaptation efforts. The focus here is on how adaptation can be best promoted and facilitated under the international climate regime.

Adaptation efforts under the current climate regime

Under the UNFCCC all parties commit to undertake national adaptation measures and to cooperate in preparing for the impacts of climate change. Special consideration is given to the least developed countries for their special needs to cope with adverse effects of climate change.[24] The least developed countries are encouraged and supported under the convention to prepare a National Adaptation Program of Action identifying priority activities that respond to their urgent and immediate needs to adapt to climate change (see chapter 8). To date, 41 least developed countries have submitted national action programs.[25] The five-year Nairobi Work Program adopted in 2005 aims to help these countries improve their understanding and assessment of the impacts of climate change and to make informed decisions on practical adaptation actions and measures.[26]

Current funding for adaptation under the UNFCCC process is mainly through the Global Environment Facility's Strategic Priority on Adaptation initiatives; additional funding will come from the UNFCCC Adaptation Fund when it is fully operational.

The international effort to date has delivered some information and capacity building on adaptation, but it has yet to facilitate significant implementation at the domestic level, access to technology, or the building of national institutions to carry the adaptation agenda forward. The effort is constrained by limited funding (see chapter 6) and the limited engagement of national planning and development agencies. The UNFCCC process has traditionally involved environment agencies; its focus on climate change may not easily lead to a comprehensive, multisectoral effort addressing adaptation.

Strengthening action on adaptation under the UNFCCC

Working through the national development process is essential to encourage early planning to strengthen climate resilience and discourage investments that heighten climate vulnerability. The UNFCCC process can complement and facilitate this process by

- *Supporting comprehensive national adaptation strategies in vulnerable countries.* These strategies would establish frameworks for action and strengthen national capacities. They would build on the National Adaptation Programs of Action, which target urgent priorities, to map out comprehensive long-term plans identifying climate risks, existing and needed adaptation capacities, and national policies and measures to fully integrate climate risk management into development decision making. In addition to organizing national adaptation efforts, the strategies could serve as a basis for targeting implementation assistance through the climate regime or through other channels.
- *Exchanging experiences and best practices, and coordinating programmatic approaches to support national, regional, and international systems for adaptation and resilience.*[27] This effort would provide guidance to countries on vulnerability assessments and on how to integrate adaptation activities into sectoral and national development planning and policies, as well as help in accessing technology for adaptation. The universal membership of the UNFCCC provides a unique forum for countries, organizations, and private entities to exchange experiences and learn from each other. Bringing national development agencies to participate in this process is essential to success. Apart from using the UNFCCC process to disseminate information, it may be useful to establish regional centers of excellence for catalyzing local, national, and regional activities. The direct impacts of climate change are felt locally, and response measures need to be tailored to local circumstances. Regional centers, with international support, can promote capacity building, coordinate research activities, and exchange experiences and best practices.
- *Providing reliable funding to assist countries in implementing high-priority measures identified in their national adaptation strategies.* Funding for adaptation largely relies on public financing (see chapter 6). Finding additional sources of adaptation finance and packaging them with existing development finance are essential for effective adaptation. Funds could come from donors, a levy on the CDM, and the tax or auction revenues from emission allowances. Equally important are defining criteria for allocating funds and setting up institutional arrangements to manage them (see chapter 6). Efficient and equitable allocation and use of adaptation finance is in everybody's interest, and wasteful use of resources can undermine public support for the whole climate agenda.

A new body under the UNFCCC may be needed to provide guidance to the parties, assess national adaptation strategies, and develop criteria for allocating resources. Such a body would need to coordinate closely with other international development agencies and have enough independence to credibly assess national strategies and resource allocation.

As mentioned early in this chapter, the current UNFCCC regime does not include adequate provisions for adaptation. The Bali Action Plan presents a great opportunity to streamline the adaptation process and mobilize adequate funding to support adaptation.

Notes

1. Energy-related emissions increased by 24 percent between 1997 (when the Kyoto Protocol was signed) and 2006; see CDIAC database (DOE 2009).
2. The Global Environmental Facility (GEF) manages projects and investments through a number of multilateral organizations, in addition to functioning as the financial mechanism for international environmental conventions, including the UNFCCC. The GEF is providing $17.2 billion in cofinancing; see GEF 2009.
3. This section is drawn from Dubash 2009.
4. Absolute emission reduction entails a net decline in emissions relative to current levels, as opposed to a shift in projected emission trajectory.
5. Baer, Athanasiou, and Kartha 2007. See also box 5.2.
6. Baumert and Winkler 2005.
7. Burtraw and others 2005; Barrett 2005.
8. See Focus A on science and chapter 4 for a discussion.
9. EU submission to UNFCCC, http://unfccc.int/files/kyoto_protocol/application/pdf/ecredd191108.pdf (accessed August 5, 2009).
10. India and China's submissions to the UNFCCC, http://unfccc.int/files/kyoto_protocol/application/pdf/indiasharedvisionv2.pdf and http://unfccc.int/files/kyoto_protocol/application/pdf/china240409b.pdf (accessed July 6, 2009). For a civil society perspective see Third World Network, "Understanding the European Commission's Climate Communication," http://www.twnside.org.sg/title2/climate/info.service/2009/climate.change.20090301.htm (accessed July 8, 2009).
11. For example, McKinsey Global Institute (2008) suggests that focused action in six policy areas could deliver about 40 percent of the abatement potential identified in their cost-curve approach.
12. Dollar and Pritchett 1998.
13. Heller and Shukla 2003.
14. Heller and Shukla 2003.
15. Bodansky and Diringer 2007.
16. Blanford, Richels, and Rutherford 2008; Blanford, Richels, and Rutherford forthcoming.
17. Winkler and others 2002.
18. Lewis and Diringer 2007.
19. See, for instance, submissions to the UNFCCC from South Africa (http://unfccc.int/files/meetings/dialogue/application/pdf/working_paper_18_south_africa.pdf) and the Republic of Korea (http://unfccc.int/resource/docs/2006/smsn/parties/009.pdf) (accessed June 2009).
20. Submissions to the UNFCCC from South Africa and the Republic of Korea: http://unfccc.int/resource/docs/2006/smsn/parties/009.pdf, (accessed June 2009).
21. Submission to the UNFCCC from South Africa: http://unfccc.int/files/meetings/dialogue/application/pdf/working_paper_18_south_africa.pdf (accessed June 2009).
22. For example, in their submissions to the UNFCCC, the United States and European Union indicate that major developing countries shall commit to formulate and submit low-carbon strategies to the UNFCCC. See UNFCCC/AWGLCA/2009/MISC.4 at http://unfccc.int/resource/docs/2009/awglca6/eng/misc04p02.pdf (accessed August 5, 2009).
23. Akanle and others 2008. See http://unfccc.int/kyoto_protocol/mechanisms/items/1673.php (accessed July 8, 2009) for information about the Kyoto Protocol's flexibility mechanisms.

24. Article 4.1 of the UNFCCC.

25. UNFCCC Secretariat, http://unfccc.int/cooperation_support/least_developed_countries_portal/submitted_napas/items/4585.php (accessed August 5, 2009)

26. Decision 2/CP.11 of the UNFCCC.

27. SEG 2007.

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focus C

Trade and climate change

The interaction between the international trade and climate change regimes has potentially major implications for developing countries. While there are positive reasons for exploring synergies between the two regimes and for aligning policies that could stimulate production, trade, and investment in cleaner technology options, instead much focus has been on using trade measures as sanctions in the global climate negotiations.

This focus on sanctions stems mainly from competitiveness concerns in countries that are now racing to reduce greenhouse gas emissions to meet Kyoto 2012 targets and beyond. These concerns have led to proposals for tariff or border tax adjustments to offset any adverse impact of capping carbon dioxide (CO_2) emissions. There is also a concern about "leakage" of carbon-intensive industries into countries that are not implementing the Kyoto Protocol.

The broad objective of bettering current and future human welfare is shared by both global trade and climate regimes. Just as the World Trade Organization (WTO) recognizes the importance of seeking to "protect and preserve the environment,"[1] the Kyoto Protocol states that parties should "strive to implement policies and measures . . . in such a way as to minimize adverse effect on international trade." The United Nations Framework Convention on Climate Change (UNFCCC) features similar language in several places, and the Doha Communiqué specifically states that "the aims of upholding and safeguarding an open and non-discriminatory multilateral trading system, and acting for the protection of the environment and promotion of sustainable development can and must be mutually supportive."[2] Both treaties thus recognize and respect each other's mandate.

Yet both climate and trade agendas have evolved largely independently through the years, despite their mutually supporting objectives and the potential for synergies. While the implementation of the Kyoto Protocol may have brought to light some conflicts between economic growth and environmental protection, the objectives of the protocol also provide an opportunity for aligning development and energy policies in ways that could stimulate production, trade, and investment in cleaner technology options.

Recent attempts to bring together the two agendas have been received with a great deal of skepticism. While trade ministers meeting in 2007 at the UNFCCC Bali Conference of Parties widely shared the view that the trade and climate regimes could buttress each other in several areas, they noted that tension between the two could arise, especially in the context of negotiations on post-Kyoto climate commitments after 2012.

A general developing-country perception is that any discussion of climate change issues (and, more broadly, environmental issues) in trade negotiations could eventually lead to "green protectionism" by high-income countries which would be detrimental to their growth prospects. They have resisted attempts to include climate issues in trade by stating that climate change issues primarily belong and have to be negotiated under the umbrella of the UNFCCC. Even within the WTO there has been a general reluctance to broaden the climate mandate in the absence of a directive from the UNFCCC. Interestingly, despite all the rhetoric, a growing number of regional trade agreements (many of which include developing countries) now have elaborate environmental provisions. However, there is little evidence to show that they have contributed in any meaningful way to achieving positive environmental outcomes.[3] Also, regional trade agreements may have limited value in addressing environmental issues that require global solutions, such as climate change.

New developments

The proposed use of punitive trade sanctions to support domestic climate action remains prominent and has gained ground in the midst of the current financial crisis. All the recent energy and climate policy bills introduced in the U.S. Congress provide for trade sanctions or tariffs (or equivalent instruments) on certain goods from those countries that do not impose controls on carbon emissions. Similarly, the European Commission's plans to tighten Europe's greenhouse gas reduction regime also recognizes the risk that new legislation could put European companies at a competitive disadvantage compared to those in countries with less stringent climate protection laws.

The issue of imposing border measures on environmental grounds has been much discussed in the economic and legal literature. The WTO and other trade agreements do allow for "exceptions" for trade measures that might otherwise violate free trade rules but that can be justified as necessary or related to an effort to protect the environment or conserve exhaustible natural resources and so long as they are "nondiscriminatory" and "least-trade-restrictive."[4] Trade measures are often justified as a mechanism to ensure compliance with multilateral environmental agreements (MEAs). Indeed MEAs such as the Convention on International Trade in Endangered Species and the Basel Convention use trade restrictions as a means to achieve MEA aims and these are accepted by all parties to the MEA. In case of climate change, however, a particularly thorny issue in assessing the compatibility of trade measures with climate change policy may arise from the application of unilateral measures based on national policies or product standards based on Processes and Production Methods, or both. The other issue with respect to "border tax adjustments" that has received little attention is what would happen to the revenue that is generated. If it is all given back to the country that is taxed it may have a very different political economy than if it stays in the country imposing the tax.

But legal experts remain divided on whether a tax on embodied carbon would be compatible with international trade regulations, because the WTO so far has not come out with clear provisions on the subject. Nonetheless, the recent proposals could have significant implications for trade in manufactures in developing countries (box FC.1).

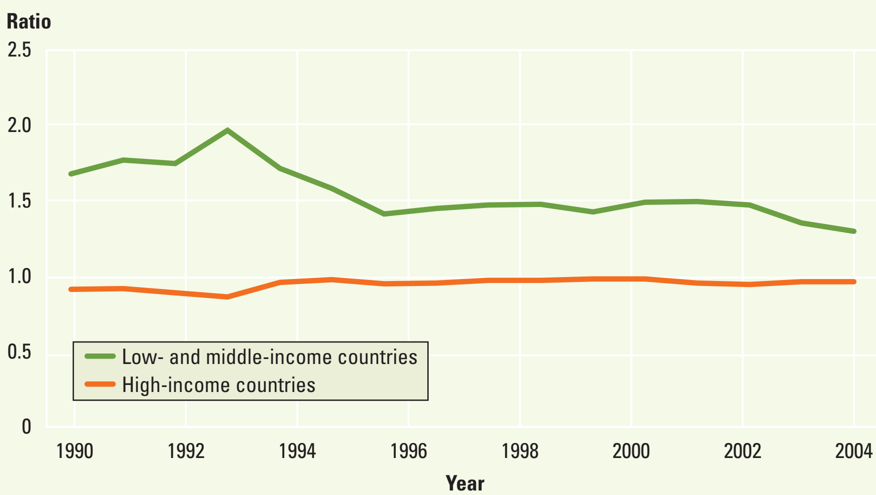
Many high-income countries also express concern that any plan that exempts developing countries from emissions limits would not be effective because carbon-intensive industries would simply shift their operations to one of the exempt countries. Carbon leakage, as such a shift is called, not only would undercut the environmental benefits of the Kyoto Protocol but also would affect the competitiveness of developed-country industries. For energy-intensive industries such as cement, and chemicals, international competitiveness is an important concern. This issue has a parallel to the "pollution havens" debate that dominated the trade and environment literature in the 1990s.

A recent World Bank study examined the evidence for any relocation of carbon-intensive industries attributable to more stringent climate policies, mostly in high-income countries. One of the factors influencing the operations of the energy-intensive sectors generally is the relative energy price in addition to land and labor costs. The study used import-export ratios of energy-intensive production in high-income countries and low- and middle-income countries as a proxy for any shift in production and trade patterns (figure FC.1).[5] The import-export ratios show an increasing trend for high-income OECD countries and a declining trend for low- and middle-income countries. While not conclusive, this seems to suggest that some relocation of energy-intensive industries may already be happening to countries that do not face caps on their greenhouse gas emissions. However, the ratio is still less than 1 for high-income countries and more than 1 for developing economies, suggesting that high-income countries continue to be net exporters and developing countries net importers of energy-intensive products.

In a similar vein, firms in some developed countries are adopting "carbon labeling" as a mechanism for mitigating climate change. Carbon labeling involves measuring carbon emissions from the production of products or services and conveying that information to consumers and those making sourcing decisions within companies. It is possible that well-designed schemes would create incentives for production in different parts of the supply chain to move to lower-emission locations. Thus, carbon labeling could be an instrument that enables consumers to exercise their desire to join the battle against climate change by using their purchasing preferences.

The downside of carbon-labeling schemes is that they are likely to have a significant impact on exports from low-income countries.[6] Fears have been raised that low-income countries will face greater difficulties exporting in a climate-constrained world where carbon emissions need to be measured and certification obtained to enable participation in carbon-labeled trade. Exports

Figure FC.1 Import-export ratio of energy-intensive products in high-income countries and low- and middle-income countries



Source: World Bank 2008.

BOX FC.1 *Taxing virtual carbon*

Should carbon be taxed where it is emitted, or at the point where goods are consumed on the basis of their "embodied" or "virtual" carbon—the amount of carbon emitted in producing and delivering the good? Many major exporting countries argue that they would be penalized by taxing carbon at the point of emission, when in fact much of this carbon is emitted in the production of goods for export—goods that are enjoyed by consumers in other countries. Based on analysis of carbon flows within a multiregional input-output table, the figure shows that China and the Russian Federation are net exporters of virtual carbon, while the European Union, the United States, and Japan are net importers.

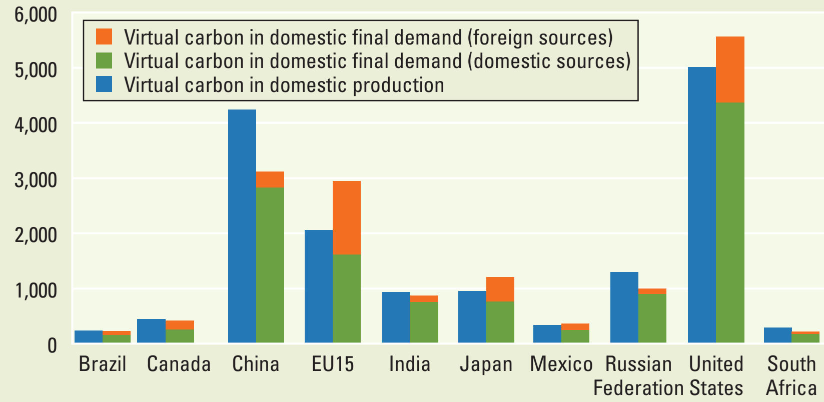
However, countries imposing a carbon tax will be concerned about competitiveness and carbon leakage effects if other countries do not follow suit, and may consider taxing virtual carbon imports to level the playing field. The table shows the effective tariff rates in addition to the existing tariffs that countries would face if a tax of $50 a ton of CO_2 were placed on the virtual carbon content of imported goods and services.

A carbon price of $50 a ton of CO_2 is in line with recent experience—emission permits in the European Emission Trading Scheme traded as high as €35 in 2008. The box table therefore suggests that virtual carbon tariff rates faced by developing countries could be significant if countries go this route.

Unilateral imposition of virtual carbon tariffs would clearly be a source of trade friction, however, damaging an international trading system that is already being stressed by the current financial crisis. Opening the door to border taxes for climate could lead to a proliferation of trade measures dealing with other areas where the competitive playing field is viewed as uneven. Accurate measurement of virtual carbon would be highly complex and subject to dispute. Moreover, placing tariffs on virtual carbon could burden low-income countries that have contributed very little to the problem of climate change.

Source: Atkinson and others 2009.

Production- and consumption-based emissions (million tons of CO_2)



Source: Atkinson and others 2009.

Note: The height of the blue bar measures total emissions from production of goods and services; the green bar represents how much carbon is emitted domestically to support domestic final demand (virtual carbon from domestic sources); the orange bar represents how much carbon is emitted abroad to support domestic final demand (the virtual carbon from foreign sources). If the height of the blue bar is greater than the sum of the other two bars, then the country is a net exporter of virtual carbon.

Average tariff on imports of goods and services if virtual carbon is taxed at $50 a ton of CO_2
(percent)

		Importing countries										
		Brazil	Canada	China	EU15	India	Japan	Mexico	Russian Federation	United States	South Africa	Average
Exporting countries	Brazil	0.0	3.4	3.2	3.2	2.8	4.0	2.7	2.6	3.0	2.9	3.1
	Canada	4.5	0.0	3.4	3.4	3.7	3.2	2.8	2.8	2.6	3.0	2.8
	China	12.1	10.5	0.0	10.5	13.4	10.4	9.9	10.0	10.3	11.1	10.5
	EU15	1.6	1.1	1.1	0.0	1.3	1.2	1.1	1.1	1.2	1.2	1.2
	India	8.3	7.8	9.2	7.7	0.0	6.8	8.1	8.7	7.9	5.3	7.8
	Japan	1.4	1.3	1.5	1.4	1.6	0.0	1.4	1.4	1.2	1.3	1.4
	Mexico	3.5	2.1	4.2	4.0	10.8	4.0	0.0	4.1	1.7	3.5	2.1
	Russian Federation	18.0	14.3	12.4	11.8	12.8	11.3	14.7	0.0	10.4	15.9	11.7
	United States	3.3	3.0	3.1	3.1	3.3	3.0	2.8	2.8	0.0	3.2	3.0
	South Africa	15.9	10.1	10.6	9.8	11.5	11.4	16.6	7.9	8.9	0.0	10.1
Average		3.7	2.9	2.2	5.0	4.5	4.8	3.3	2.6	3.0	2.9	

Source: Atkinson and others 2009.

Note: The last column is the trade-weighted average tariff faced by the exporting country; the last row is the trade-weighted average tariff applied by the importing country.

from low-income countries typically depend on long-distance transportation and are produced by relatively small firms and tiny farms that will find it difficult to participate in complex carbon-labeling schemes.

There is a significant knowledge gap to be filled regarding scientific studies of the structure of carbon emissions throughout international supply chains that include low-income countries. The small number of existing studies suggests that emissions patterns are highly complex, and an important finding is that geographic location alone is a poor proxy for emissions, because favorable production conditions may more than offset a disadvantage in transport. For example, Kenyan-produced roses airfreighted to and sold in Europe are associated with considerably lower carbon emissions than roses produced in the Netherlands.

The design and implementation of carbon labeling will also need to take into account a number of complex, technical challenges.[7] First, using secondary data from producers in rich countries to estimate the carbon emissions of producers in low-income countries will not capture the fact that the technologies being applied in rich and low-income countries are substantially different. A second technical issue relates to the use of emission factors—the amount of carbon emitted during particular parts of the manufacture and use of products—and how they should be calculated. A third issue is the choice of system boundaries, which define the extent of processes that are included in the assessment of greenhouse gas emissions. Estimates of the carbon footprint of a system, product, or activity will also depend on where the system boundary is drawn.

The positive agenda

The other area where trade and climate have recently overlapped relates to technology transfer. Given the limitations of the Clean Development Mechanism in delivering the kind and magnitude of technology transfer needed to deal with increasing greenhouse gas emissions in the developing world (see chapter 6), it has been suggested that broader trade and investment rules could be one way to speed up transfer of technology.[8] Liberalizing trade in environmental goods and services has been on the agenda of the WTO Doha Round since the beginning. All WTO members agree that environmental goods liberalization should be geared toward environmental protection. Yet very little has been achieved owing to the differing perceptions of developed and developing countries on what goods are to be liberalized and how to liberalize.

Efforts have been made, including by the World Bank,[9] to move these negotiations forward by identifying climate-friendly goods and services that currently face tariff and nontariff barriers to trade, and making the removal of these barriers through the WTO negotiations a priority. This effort has proved challenging, because WTO members have yet to agree on a definition of "climate friendly" that both contributes to climate policy objectives and generates a balanced distribution of trade benefits among members. Two particular areas of controversy involve "dual use" technologies that may be used to reduce emissions as well as to meet other consumer needs, and agricultural products, which are mired in a very contentious part of the Doha negotiations.

The other issue that often goes unnoticed is the huge potential for trade between developing countries (South-South trade) in clean technology. Traditionally developing countries have been importers of clean technologies, while developed countries have been exporters. However, as a result of their improving investment climate and huge consumer base, developing countries are increasingly becoming major players in the manufacture of clean technologies.[10] A key development in the global wind power market is the emergence of China as a significant player, both in manufacturing and in investing in additional wind power capacity. Similarly other developing countries have emerged as manufacturers of renewable energy technologies. India's solar photovoltaic manufacturing capacity has increased several times in the past four years, while Brazil continues to be a world leader in the production of biofuels. These developments call for liberalizing bilateral trade in clean technologies that could also facilitate buoyant South-South technology transfer in the future.

The way forward on trade and climate change

Countries have generally been reluctant to bring the trade and climate regimes closer for fear of one overwhelming the other. This is unfortunate because trade in clean energy technologies potentially offers an economic opportunity for developing countries that are emerging as major producers and exporters of these technologies.

Progress in the trade regime is possible even on very complex subjects. The success of the WTO's 1997 Information Technology Agreement suggests that implementation of any agreement on climate-friendly goods and technologies will certainly need to follow a phased approach to enable developing countries to deal gradually with implementing liberalization, including increasing the efficiency of customs administration and harmonizing customs classifications. This should be supported through a package of financial and technical assistance measures. Postponing action on the trade and climate agenda until another lengthy round of WTO negotiations beyond the Doha Round is risky because of the imminent danger that climate-related trade sanctions of the variety proposed in the United States and the European Union could become a reality.

If climate-related trade measures bite deeply enough, developing countries can use the trade and climate negotiations to push back, or they may choose to adapt to the new policies and standards set by their major trading partners, in order to maintain access to their markets. In either case, developing countries will need to build their capacity to better understand and respond to these developments. Further, the need to push for financial and technology transfer as a part of any global deal on trade and climate change could not be more emphasized.

While there could be many benefits to bringing the trade and climate regimes closer, the potential for harm to the international trade regime from actions such as unilateral imposition of border taxes on carbon should not be underestimated, especially since the burden will fall disproportionately on developing countries. It is thus in the interest of developing countries to ensure that the pursuit of global climate objectives is compatible with maintaining a fair, open, and rule-based multilateral trading system as a foundation for their growth and development. Developed countries also have an important stake in the multilateral trading system and bear a major responsibility for ensuring that the system is maintained. While developing countries have a major stake in maintaining a fair, open, and rules-based multilateral trading system as a foundation for their growth and development, developed countries have a bigger stake because the onus is on them to maintain that system.

Notes

1. Preamble to the Marrakesh Agreement that established the WTO in 1995.
2. Quoted in World Bank 2008.
3. Gallagher 2004.
4. See article XX (b) and (g) of the 1947 General Agreement on Tariffs and Trade. WTO 1986.
5. World Bank 2008.
6. Brenton, Edwards-Jones, and Jensen 2008.
7. Brenton, Edwards-Jones, and Jensen 2008.
8. Brewer 2007.
9. World Bank 2008.
10. World Bank 2008.

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FÜNFZIG SCHILLING
BANCA D'ITALIA
ÖTEZER FORINT
MAGYAR NEMZETI BANK
5000
FORINT
THE UNITED STATES OF AMERICA
TWENTY DOLLARS
STO KORUN ČESKÝCH
SUID-AFRIKAANSE RESERWEBANK
SINGAPORE
This note is legal tender
TWO DOLLARS
TEN DOLLARS
TWENTY
HONGKONG DOLLARS
港幣貳拾元
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Banque de France
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BANCA D'ITALIA
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SUOMEN PANKKI
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Generating the Funding Needed for Mitigation and Adaptation

Developed countries must take the lead in combating climate change. But mitigation will be neither effective nor efficient without abatement efforts in developing countries. Those are two key messages of earlier chapters. But there is a critical third dimension to meeting the climate challenge: equity. An equitable approach to limiting global emissions of greenhouse gases has to recognize that developing countries have legitimate development needs, that their development may be jeopardized by climate change, and that they have contributed little, historically, to the problem.

Flows of climate finance, both fiscal transfers and market transactions, from developed to developing countries represent the principal way to reconcile equity with effectiveness and efficiency in dealing with the climate problem. Financial flows can help developing countries reduce their greenhouse gas emissions and adapt to the effects of climate change. In addition, there will be financing needs related to developing and diffusing new technologies. Mitigation, adaptation, and the deployment of technologies have to happen in a way that allows developing countries to continue their growth and reduce poverty. This is why additional financial flows to developing countries are so crucial.

The funding required for mitigation, adaptation, and technology is massive. In developing countries mitigation could cost $400 billion a year over the next 20 years, and over the period 2010 to 2050 adaptation investments could average $75 billion a year. These figures can be compared with current development assistance of roughly $100 billion a year. Yet efforts to raise funding for mitigation and adaptation have been woefully inadequate, standing at less than 5 percent of projected needs.

At the same time, existing financing instruments have clear limits and inefficiencies. Contributions from high-income country governments are affected by fragmentation and the vagaries of political and fiscal cycles. Despite all its success, the Clean Development Mechanism (CDM), the main source of mitigation finance to date for developing countries, has design shortcomings and operational and administrative limits. The scope for raising adaptation funding through the CDM, now the main source of income for the Adaptation Fund, is thus also limited.

So new sources of finance will have to be tapped. Governments will have to step in, but it will be equally important to develop new innovative funding mechanisms and to leverage private finance. The private sector

Key messages

Climate finance provides the means to reconcile equity with effectiveness and efficiency in actions to reduce emissions and adapt to climate change. But current levels fall far short of estimated needs—total climate finance for developing countries is $10 billion a year today, compared with projected requirements of $75 billion for adaptation and $400 billion for mitigation annually by 2030. Filling the gap requires reforming existing carbon markets and tapping new sources, including carbon taxes. Pricing carbon will transform national climate finance, but international financial transfers and trading of emission rights will be needed if growth and poverty reduction in developing countries are not to be impeded in a carbon-constrained world.

will have a key role in financing mitigation through carbon markets and related instruments. But official flows or other international funding will be an important complement to build capacity, correct market imperfections, and target areas overlooked by the market. Private finance will also be important for adaptation, because private agents—households and firms—will carry much of the adaptation burden. But good adaptation is very closely linked to good development, and those most in need of adaptation assistance are the poor and disadvantaged in the developing world. This means public finance will have a key role.

In addition to raising new funds, using available resources more effectively will be crucial. This calls both for exploiting synergies with existing financial flows, including development assistance, and for coordinating implementation. The scale of the financing gaps, the diversity of needs, and differences in national circumstances require a broad range of instruments. Concerns with effectiveness and efficiency mean that finance for climate change must be raised and spent coherently.

Financing needs are linked to the scope and timing of any international agreement on climate change. The size of the adaptation bill will depend directly on the effectiveness of the agreement. For mitigation, chapter 1 shows that delayed implementation of emission reductions, whether in developed or developing countries, risks hugely increasing the cost of stabilizing the climate. The overview chapter shows that on a global least-cost path for climate stabilization, a large fraction (65 percent or more)[1] of the needed mitigation would occur in developing countries. The cost of stabilizing the climate can thus be substantially reduced if developed countries provide enough financial incentives for developing countries to switch to lower carbon paths. As other chapters emphasize, however, finance will need to be combined with access to technology and capacity building if developing countries are to shift to a lower-carbon development path.

This chapter deals with raising enough finance to reduce emissions and cope with the impacts of unavoidable changes. It assesses the gap between the projected needs for mitigation and adaptation finance compared with sources of finance available up to 2012. It looks at inefficiencies in the existing climate-finance instruments and discusses potential funding sources beyond the ones curently available (table 6.1). And it presents models for increasing the effectiveness of existing schemes, particularly the Clean Development Mechanism, and for allocating adaptation finance. Throughout the focus is on financing needs in developing countries,

Table 6.1 Existing instruments of climate finance

Type of instrument	Mitigation	Adaptation	Research, development, and diffusion
Market-based mechanisms to lower the costs of climate action and create incentives	Emissions trading (CDM, JI, voluntary), tradable renewable energy certificates, debt instruments (bonds)	Insurance (pools, indexes, weather derivatives, catastrophe bonds), payment for ecosystem services, debt instruments (bonds)	
Grant resources and concessional finance (levies and contributions including official development assistance and philanthropy) to pilot new tools, scale up and catalyze action, and act as seed money to leverage the private sector.	GEF, CTF, UN-REDD, FIP, FCPF	Adaptation Fund, GEF, LDCF, SCCF, PPCR and other bilateral and multilateral funds	GEF, GEF/IFC Earth Fund, GEEREF
Other instruments	Fiscal incentives (tax benefits on investments, subsidized loans, targeted tax or subsidies, export credits), norms and standards (including labels), inducement prizes and advanced market commitments, and trade and technology agreements		

Source: WDR Team.

Note: CDM = Clean Development Mechanism; CTF = Clean Technology Fund; FCPF = Forest Carbon Partnership Facility; FIP = Forest Investment Program; GEEREF = Global Energy Efficiency and Renewable Energy Fund (European Union); GEF = Global Environment Facility; IFC = International Finance Corporation; JI = Joint Implementation; LDCF = Least Developed Country Fund (UNFCCC/GEF); PPCR = Pilot Program for Climate Resilience; SCCF = Strategic Climate Change Fund (UNFCCC/GEF); UN-REDD = UN Collaborative Program on Reduced Emissions from Deforestation and Forest Degradation.

where the questions of effectiveness, efficiency, and equity all come together.

The financing gap

Successfully tackling climate change will cost trillions. How many depends on how ambitious the global response is, how it is structured, how the measures are timed, how effectively they are implemented, where mitigation takes place, and how the money is raised. Bearing the costs will be the international community, national governments, local governments, firms, and households.

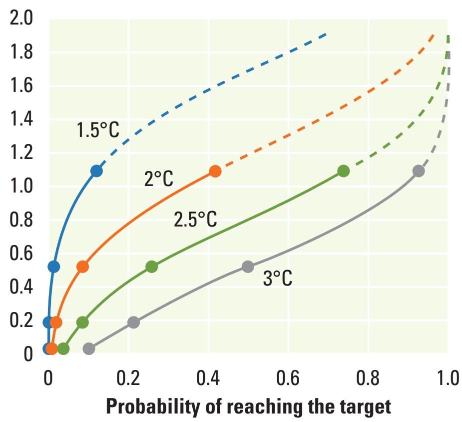
The need for finance

According to the Intergovernmental Panel on Climate Change (IPCC), which reviewed cost estimates in its fourth assessment, the cost of cutting global greenhouse gas emissions by 50 percent by 2050 could be in the range of 1–3 percent of GDP.[2] That is the minimum cut most scientists believe is needed to have a reasonable chance of limiting global warming to 2–2.5°C above preindustrial temperatures (see overview).

But mitigation costs are sensitive to policy choices. They increase steeply with the stringency of the emission reduction target and with the certainty of reaching it (figure 6.1). Global mitigation costs will also be higher if the world deviates from the least-cost emission reduction path. As earlier chapters explain, not including developing countries in the initial mitigation effort would increase global costs significantly (a consideration that led to the establishment of the Clean Development Mechanism under the Kyoto Protocol). Similarly, not considering all mitigation opportunities would markedly increase overall costs.

It is also important to distinguish between mitigation costs (the additional costs of a low-carbon project over its lifetime) and incremental capital costs (the extra investment needed at the outset of the project). Because many clean investments have high up-front capital costs, followed later by savings in operating costs, the incremental capital needs tend to be higher than the lifetime costs reported in mitigation models. In some cases the difference can be as much as a factor of two to four.[3] For fiscally constrained developing countries these high up-front capital costs can be a significant disincentive to invest in low-carbon technologies.

Figure 6.1 Annual mitigation costs rise with the stringency and certainty of the temperature target



Source: Schaeffer and others 2008.

Table 6.2 reports a range of estimates for annual investments in developing countries needed to stabilize atmospheric concentrations of CO_2e (all greenhouse gases summed up and expressed in terms of their carbon dioxide equivalent) at 450 or 550 parts per million (ppm) over the next decade, as well as the adaptation investments estimated to be required in 2030. Focusing on the 450 ppm target, the median mitigation cost is $400 billion a year in 2030 and the range is roughly $140 billion to $675 billion a year. For adaptation the most comparable estimates are the medium-term figures produced by the United Nations Framework Convention on Climate Change (UNFCCC) and the World Bank, which range from $30 billion to $90 billion (in round numbers), with a median of $75 billion a year.

Many, but not all, of the identified adaptation needs would require public expenditures. According to the UNFCCC secretariat,[4] private funding would cover about a quarter of identified investment, although this estimate is unlikely to capture the full private investment in adaptation.

These numbers give a rough indication of the adaptation cost, but they are neither particularly accurate nor fully comprehensive. Most were derived from rules of thumb, dominated by the cost of climate-proofing future infrastructure. They

Table 6.2 Additional annual climate-change investments needed in developing countries
$ billions

Source of estimate	**Target**		
Mitigation investments	**CO_2 concentration**	**2010–20**	**2030–40**
United Nations Framework Convention on Climate Change (UNFCCC)	550 ppm		82–87
International Institute for Applied System Analysis (IIASA)	450 ppm	28–93	137–240
International Energy Agency (IEA) Energy Technology Perspectives	550 ppm 450 ppm	230 600	
McKinsey & Company	450 ppm	60	675
MiniCAM	450 ppm		168
Adaptation investments	**Included measures**	**2010–15**	**2030**
Short-term World Bank	Cost of climate-proofing development assistance, foreign and domestic investment	9–41	
Stern Review	Cost of climate-proofing development assistance, foreign and domestic investment	4–37	
United Nations Development Program	Same as World Bank, plus cost of adapting Poverty Reduction Strategy Papers and strengthening disaster response	86–109	
Oxfam	Same as World Bank plus cost of National Adaptation Plan of Action and nongovernmental organization projects	> 50	
Medium term UNFCCC	2030 cost in agriculture, forestry, water, health, coastal protection, and infrastructure		28–67
Project Catalyst	2030 cost for capacity building, research, disaster management and the UNFCCC sectors (most vulnerable countries and public sector only)		15–37
World Bank (EACC)	Average annual adaptation costs from 2010 to 2050 in the agriculture, forestry, fisheries, infrastructure, water resource management, and coastal zone sectors, including impacts on health, ecosystem services, and the effects of extreme-weather events.		>80

Sources: For mitigation, UNFCCC 2008a, IIASA 2009; IEA 2008; McKinsey Global Institute 2009 and additional data communication from McKinsey for 2030, using a dollar-to-Euro exchange rate of $1.50 to €1.00; MiniCAM figures from Edmonds and others 2008 and additional data provided by Jae Edmonds; for adaptation, Agrawala and Fankhauser 2008; World Bank 2009b; and Project Catalyst 2009.

Note: Concentration targets are carbon dioxide equivalent (CO_2e) targets for all greenhouse gases. IEA figures are annual averages through 2050.

underestimate the diversity of the likely adaptation responses and ignore changes in behavior, innovation, operational practices, or locations of economic activity. They also ignore the need for adaptation to nonmarket impacts such as those on human health and natural ecosystems. Some of the omitted options could reduce the adaptation bill (for example, by obviating the need for costly structural investments); others would increase it.[5] The estimates also do not consider residual damages beyond effective adaptation. A recent attempt to encompass these complexities in measuring adaptation costs is reported in box 6.1.

Adaptation cost estimates also ignore the close links between adaptation and development. Although few studies are clear on this point, they measure the extra spending to accommodate climate change over and above what would have been spent on climate-sensitive investments anyway, such as those accommodating the consequences of income and population growth or correcting an existing adaptation deficit. But, in practice, the distinction between adaptation funding and development funding is not easy. Investments in education, health, sanitation, and livelihood security, for example, constitute good development. They also help reduce socioeconomic vulnerability to both climatic and nonclimatic stress factors. Certainly in the short term, development assistance is likely to be a key complement to close adaptation deficits, to reduce climate

BOX 6.1 *Costing adaptation to climate change in developing countries*

A World Bank study published in 2009 on the economics of adaptation to climate change provides the most recent and comprehensive estimates of adaptation costs in developing countries, covering both country case studies and global estimates of adaptation costs. Key elements of the design of the study include:

Coverage. The sectors studied comprise agriculture, forestry, fisheries, infrastructure, water resource management, and coastal zones, including impacts on health and ecosystem services, and the effects of extreme weather events. Infrastructure is broken down into transport, energy, water and sanitation, communications, and urban and social infrastructure.

Baseline. The estimates do not include the existing "adaptation deficit"—the extent to which countries are incompletely or suboptimally adapted to existing climate variability.

Level of adaptation. For most sectors the study estimates the cost of restoring welfare to the level that would exist without climate change.

Uncertainty. To capture the extremes of possible climate outcomes the study uses results from general circulation models spanning the wettest and driest climate projections, under the IPCC's A2 scenario of possible socioeconomic and emissions trajectories.

Based on these design elements, the study arrives at bottom-line estimates of the global cost of adaptation to climate change in developing countries upwards of $80 billion a year on average from 2010 to 2050.[a]

Source: World Bank 2009.
a. To be updated for the final release based on World Bank 2009.

risks, and to increase economic productivity. But new adaptation finance is also needed.

Mitigation finance available to date

Over the coming decades trillions of dollars will be spent to upgrade and expand the world's energy and transport infrastructure. These massive investments present an opportunity to decisively shift the global economy onto a low-carbon path—but they also raise the risk of a high-carbon lock-in if the opportunity is missed. As earlier chapters show, new infrastructure investments need to be steered to low-carbon outcomes.

Both public and private flows will be needed to fund these investments. Many instruments already exist (table 6.1). All will have a role in catalyzing climate action: mobilizing additional resources; reorienting public and private flows toward low-carbon and climate-resilient investments; and supporting the research, development, and deployment of climate-friendly technologies.

The public sector will provide capital mostly for big infrastructure projects, but a large part of the investment to create a low-carbon economy—from energy-efficient machinery to cleaner cars to renewable energy—will come from the private sector. Currently, governments account for less than 15 percent of global economywide investment, although they largely control the underlying infrastructure investments that affect the opportunities for energy-efficient products.

There are various ways to encourage private investment in mitigation,[6] but the most prominent market instrument involving developing countries has been the Clean Development Mechanism. It has triggered more than 4,000 recognized emission reduction projects to date. Other similar mechanisms, such as Joint Implementation (the equivalent mechanism for industrial countries) and voluntary carbon markets, are important for some regions (transition countries) and sectors (forestry) but are much smaller. Under the CDM, emission reduction activities in developing countries can generate "carbon credits"—measured against an agreed baseline and verified by an independent entity under the aegis of the UNFCCC—and trade them on the carbon market. For example, a European power utility may acquire emission reductions (through direct purchase or financial support) from a Chinese steel plant embarking on an energy-efficiency project.

The financial revenues the CDM generates are modest relative to the amount of mitigation money that will have to be raised. But they constitute the largest source of mitigation finance to developing countries to date. Between 2001, the first year CDM projects could be registered, and 2012, the end of the Kyoto commitment period, the CDM is expected to produce some 1.5 billion tons of carbon dioxide equivalent (CO_2e) in emission reductions, much through renewable energy, energy efficiency, and fuel switching. This could raise $18 billion ($15 billion to $24 billion) in direct carbon revenues for developing countries, depending on the price of carbon (table 6.3).[7] In addition each dollar of carbon revenue leverages on average $4.60 in investment and possibly up to $9.00 for some renewable energy projects. It is estimated that some $95 billion in clean energy investment benefited from the CDM over 2002–08.

In comparison, official development assistance for mitigation was about $19 billion over 2002–07,[8] and sustainable energy investment in developing countries totaled approximately $80 billion over 2002–08.[9]

Donors and international financial institutions are establishing new financing vehicles to scale up their support for low-carbon investment in the lead-up to 2012 (table 6.4). Total finance under these initiatives amounts to $18.9 billion up to 2012, although this figure combines mitigation and adaptation finance.

The current inadequacy of mitigation funding is obvious. Combining the donor funds in table 6.4 (and counting them as if committed solely to mitigation) with the projected CDM finance to 2012 produces mitigation finance of no more than roughly $37 billion up to 2012, or less than $8 billion a year. This falls far short of the estimated mitigation financing needs in developing countries of $400 billion a year.

Table 6.3 Potential regional CDM delivery and carbon revenues (by 2012)

By region	Millions of certified emission reductions[a]	$ millions	Percentage of total
East Asia and Pacific	871	10,453	58
China	786	9,431	52
Malaysia	36	437	2
Indonesia	21	252	2
Europe and Central Asia	10	119	1
Latin America and the Caribbean	230	2,758	15
Brazil	102	1,225	7
Mexico	41	486	3
Chile	21	258	1
Argentina	20	238	1
Middle East and North Africa	15	182	1
South Asia	250	3,004	17
India	231	2,777	16
Sub-Saharan Africa	39	464	3
Nigeria	16	191	1
Developed countries	85	1,019	6
By income			
Low income	46	551	3
Nigeria	16	191	1
Lower middle income	1,127	13,524	75
China	786	9,431	53
India	231	2,777	16
Indonesia	21	252	2
Upper middle income	242	2,906	16
Brazil	102	1,225	7
Mexico	41	486	3
Malaysia	36	437	2
Chile	21	258	1
Argentina	20	238	1
High income	85	1,019	6
Korea, Rep. of	54	653	4
Total	**1,500**	**18,000**	**100**

Source: UNEP 2008.
Note: Volumes include withdrawn and rejected projects.
a. 1 million certified emission reductions = 1 million tons of CO_2e.

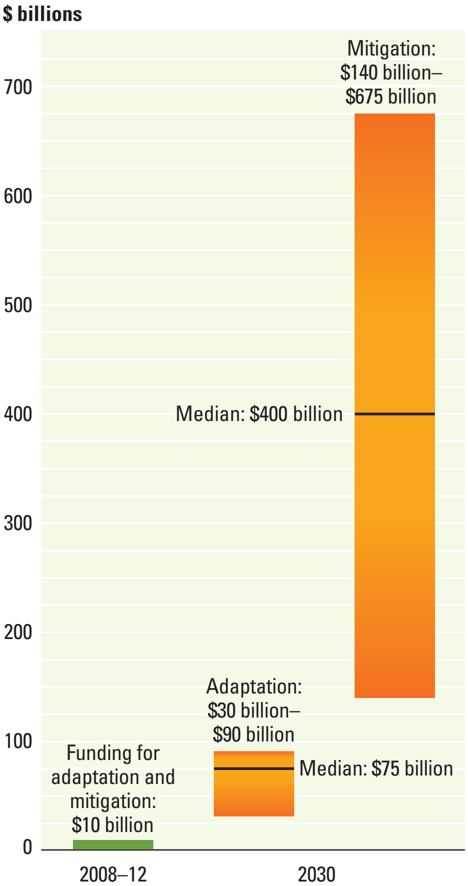
Adaptation finance available to date

Funding for adaptation started to flow only recently. The main existing source of adaptation funding is international donors, channeled either through bilateral agencies or through multilateral institutions like the Global Environment Facility (GEF) and the World Bank.

The establishment of the Adaptation Fund in December 2007, a funding mechanism with its own independent source of finance, was an important development. Its main income source is the 2 percent levy on the CDM, a novel financing source (discussed in more detail later) that could raise between $300 million and $600 million over the medium term, depending on the carbon price (see table 6.4 and endnote 7).

Excluding private finance, $2.2 billion to $2.5 billion is projected to be raised for adaptation from now to 2012, depending on what the Adaptation Fund raises. The

Figure 6.2 The gap is large: Estimated annual climate funding required for a 2°C trajectory compared with current resources



Source: See table 6.1.

potential adaptation finance now available is less than $1 billion a year, against funding requirements of $75 billion a year over the medium term (see table 6.2). Figure 6.3 compares the annual climate finance available over 2008–12 (both mitigation and adaptation, roughly $10 billion a year), with the projected medium-term financing needs.

Table 6.4 New bilateral and multilateral climate funds

Fund	Total amount ($ millions)	Period
Funding under UNFCCC		
Strategic Priority on Adaptation	50 (A)	GEF 3-GEF 4
Least Developed Country Fund	172 (A)	As of October 2008
Special Climate Change Fund	91 (A)	As of October 2008
Adaptation Fund	300–600 (A)	2008–12
Bilateral initiatives		
Cool Earth Partnership (Japan)	10,000 (A+M)	2008–12
ETF-IW (United Kingdom)	1,182 (A+M)	2008–12
Climate and Forest Initiative (Norway)	2,250	
UNDP-Spain MDG Achievement Fund	22 (A) / 92 (M)	2007–10
GCCA (European Commission)	84 (A) / 76 (M)	2008–10
International Climate Initiative (Germany)	200 (A) / 564 (M)	2008–12
IFCI (Australia)	160 (M)	2007–12
Multilateral initiatives		
GFDRR	15 (A) (of $83 million in pledges)	2007–08
UN-REDD	35 (M)	
Carbon Partnership Facility (World Bank)	500 (M) (140 committed)	
Forest Carbon Partnership Facility (World Bank)	385 (M) (160 committed)	2008–20
Climate Investment Funds, includes	6,200 (A+M)	2009–12
Clean Technology Fund	4,800 (M)	
Strategic Climate Fund, including	1,400 (A+M)	
Forest Investment Programme	350 (M)	
Scaling up renewable energy	200 (M)	
Pilot Program for Climate Resilience	600 (A)	

Source: UNFCCC 2008a plus updates by authors.

Note: For a number of bilateral initiatives, part of the funds will be distributed through multilateral initiatives (for example, some pledges to the Climate Investment Funds or the Forest Carbon Partnership Facility). This leads to some double counting and makes it difficult to draw an accurate picture of upcoming climate change resources in developing countries. The Climate Investment Funds are managed by the World Bank and implemented by all multilateral development banks. All data for the Climate Investment Funds are as of July 2009—$250 million of the Strategic Climate Fund was unallocated at that time, and the Scaling up Renewable Energy fund will require minimum pledges of $250 million before it becomes operational. A = funding devoted to adaptation; M = funding devoted to mitigation; ETF-IW = Environmental Transformation Fund-International Window; GCCA = Global Climate Change Alliance; IFCI = International Forest Carbon Initiative; UN-REDD = UN Collaborative Program on Reduced Emissions from Deforestation and Forest Degradation; GFDRR = Global Facility for Disaster Reduction and Recovery. Pledges to the Climate and Forest Initiative (Norway) stood at $430 million in June 2009.

Inefficiencies in existing climate-finance instruments

Inefficiency could take what is already projected to be a very large and costly endeavor and make it even more expensive. So there is an obvious case for ensuring that climate finance is generated and spent efficiently. Three aspects of the efficiency of climate finance are considered below: the fragmentation of climate finance into multiple funding sources, the limitations of carbon offset markets for mitigation, and the potential costs of taxing certified emission reductions (CERs) to finance the Adaptation Fund.

Fragmentation of climate finance

There is a risk of proliferation, illustrated in table 6.4, of special-purpose climate funds. Fragmentation of this sort threatens to reduce the overall effectiveness of climate finance, because as transaction costs increase, recipient country ownership lags, and alignment with country development objectives becomes more difficult. Each new source of finance, whether for development or climate change, carries with it a set of costs. These include transaction costs (which rise in aggregate as the number of funding sources increases), inefficient allocations (particularly if funds are narrowly defined), and limitations on scaling up. The current fragmentation and the low level of resources highlights the importance of the ongoing negotiations about a climate-financing architecture adequate to mobilize resources at scale and to deliver efficiently across a wide range of channels and instruments.

While there is not an exact parallel between climate finance and development aid, some of the lessons from the aid-effectiveness literature are highly relevant to climate finance. Concern about the negative effects of aid fragmentation was one of the key drivers of the Paris Declaration on Aid Effectiveness. In that declaration, most recently reaffirmed in the Accra Agenda for Action, both aid donors and recipients committed to incorporate the key tenets of ownership, alignment, harmonization, results orientation, and mutual accountability into their development activities.

The Paris Declaration raises important issues for financing climate investments in developing countries, many of which are widely accepted and reflected in negotiation documents, such as the Bali Action Plan:[10]

- *Ownership*. Building a shared consensus that climate change is a development issue, a central tenet of this Report, will be key in building country ownership. This consensus view must then be built into country development strategies.
- *Alignment*. Ensuring alignment between climate actions and country priorities is the second critical step in increasing the effectiveness of climate finance. Moving from the project to the sector and program level can facilitate this process. Predictability and sustainability of finance is another key aspect of alignment. Stop-start climate-action programs, driven by the volatility of finance, will reduce overall effectiveness.
- *Harmonization*. To the extent that the various climate funds have divergent purposes, this fragmentation of climate finance presents a great challenge to harmonizing different sources of finance and exploiting synergies among adaptation, mitigation, and development finance.
- *Results*. The results agenda for climate action is not substantially different from those of other development domains. Designing and implementing meaningful outcome indicators will be key to maintaining public support for climate finance and building country ownership for climate action.
- *Mutual accountability*. Weak progress toward Kyoto targets by many developed countries puts their accountability for climate action in the spotlight. An essential part of any global agreement on climate change must be a framework that holds high-income countries accountable for moving toward their own emission targets and for providing climate finance, and that also holds developing countries accountable for climate actions and uses of climate finance, as established in the Bali Action Plan. Beyond provision of resources, monitoring and reporting of climate finance flows and verification of results are a central topic of the ongoing climate negotiations.

In addition to the sources of finance, an important question is what investments climate funds should finance and the associated financing modalities. While some climate investments will be for individual projects—low-carbon power plants, for example—efficiencies can, in many instances, be gained by moving to the sector or program level. For adaptation, finance at the country level should in most cases be commingled with overall development finance, not used for specific adaptation projects.

More generally, rather than being overly prescriptive, climate finance could emulate the poverty reduction strategy approach now implemented in many low-income countries. This entails linking aid resources targeted at reducing poverty to a poverty reduction strategy prepared by the recipient country. Based on an analysis of poverty and a definition of country priorities, as validated by participatory processes with civil society, the strategy becomes the basis for broad budget support by donors to finance a program of action aimed at reducing poverty. Individual projects become the exception rather than the rule. If countries integrate climate action into their development strategies, a similar approach to climate finance should be feasible.

Inefficiencies of the Clean Development Mechanism

The principal instrument for catalyzing mitigation in developing countries is the CDM. It has grown beyond initial expectations, demonstrating the ability of markets to stimulate emission reductions, provide essential learning, raise awareness, and build capacity. But the CDM contains some inherent inefficiencies, raising questions about the overall process and its efficiency as a financing instrument:

Questionable environmental integrity. The long-term success of the CDM can be best assessed by its contribution to measurably reducing greenhouse gas emissions. In order not to dilute the environmental effectiveness of the Kyoto Protocol, CDM emission reductions must be additional to the reductions that would have occurred otherwise. The extent of additionality provided by the CDM has been debated vigorously.[11] The additionality of individual projects is difficult to prove and even more difficult to validate, because the point of reference is by definition a counterfactual reality that can never be incontrovertibly argued or conclusively proven. Because debates on baseline and additionality concerns continue to plague the CDM process, it is time to explore alternative, and simpler, approaches to demonstrate additionality. Approaches such as benchmarks and a positive list of specific desired activities should be explored further to streamline project preparation and monitoring. Revisiting additionality will not only address major inefficiencies in CDM operation but can also help to increase the credibility of the mechanism.

Insufficient contribution to sustainable development. The CDM was created with two objectives: the global mitigation of climate change; and the sustainable development of developing countries. But the CDM has been more effective in reducing mitigation costs than in advancing sustainable development.[12] A project is deemed to contribute to sustainable development if national authorities sign off on it, acknowledging a wide range of local co-benefits in line with their development priorities (box 6.2). While many critics accept this broad definition,[13] some nongovernmental organizations have found flaws both in the acceptance of certain project types (such as hydropower, palm oil plantations, and the destruction of industrial gases) and in implementation. A closer look at the CDM project pipeline suggests that the treatment of sustainable development in project documents is sketchy and uneven and that project developers display only a rudimentary concern for or understanding of the concept.

Weak governance and inefficient operation. The CDM is unique in regulating a market dominated by private players through an executive board—essentially a United Nations committee—that approves the calculation methods and projects that create the market's underlying asset. The credibility of the CDM depends largely on the robustness of its regulatory framework and the private sector's confidence in the opportunities the mechanism provides.[14] Complaints are mounting about the continuing lack of transparency and predictability in the board's decision making.[15] At the same time, the CDM architecture has begun to show some weaknesses that are signs of it being a victim of success. There have been copious complaints about yearlong delays in the approval of methodologies[16] and the one- to two-year time lag in the assessment of projects.[17] These are significant constraints to the continuing growth of the CDM as a key instrument to support mitigation efforts in developing countries.

Limited scope. CDM projects are not evenly distributed. A full 75 percent of sales revenues from offsets accrue to Brazil, China, and India (see table 6.3). The CDM has pretty much bypassed low-income countries, which have received only 3 percent of carbon revenues, a third of them for

BOX 6.2 *Assessing the co-benefits of the CDM*

The Clean Development Mechanism produces three broad categories of potential host-country co-benefits (apart from the financial flow from carbon credit sales): the transfer and dissemination of technologies; the contribution to employment and economic growth; and the contribution to environmentally and socially sustainable development.

The extent to which projects contribute to these three objectives can be gauged by looking at project design documents, which can be searched for keywords associated with different co-benefits. This approach was used by Haites, Maosheng, and Seres to assess the technology transfer benefits of the CDM and by Watson and Fankhauser to assess contributions to economic growth and sustainable development.

Haites, Maosheng, and Seres found that only about a third of CDM projects claim to transfer technology, by passing on equipment, know-how, or both. A closer look reveals that they are predominantly projects involving foreign sponsors. Only a quarter of projects developed unilaterally by the host country claim to transfer technology. Technology transfer is also associated with larger projects. Although only a third of projects transfer technology, they account for two-thirds of emission reductions. Projects explicitly labeled and processed as "small" projects lead to technology transfer in only 26 percent of the cases.

But technology transfer is a difficult concept to define. For mitigation, it tends to be not so much proprietary technology that is shared but operational and managerial know-how of how to run a particular process. A study by Dechezlepretre and colleagues that specifically looked at the transfer of technologies protected by patent found that the Kyoto Protocol did not accelerate technology flows, though it may have stimulated innovation more generally.

Watson and Fankhauser found that a full 96 percent of projects claim to contribute to environmental and social sustainability, but most of these claims relate to contributions to economic growth and employment in particular. Just over 80 percent of projects claim some employment impact, and 23 percent contribute to a better livelihood. There are relatively lower employment benefits from industrial gas projects (hydrofluorocarbon, perfluorocarbon, and nitrous oxide reduction—18 percent) and fossil-fuel switching projects (43 percent) than with other sectors, where at least 65 percent of projects state employment benefits.

Applying a more traditional and narrower definition of sustainable development, 67 percent of projects claim training or education benefits (increasing human capital), 24 percent reduce pollution or produce environmental co-benefits (increasing natural capital), and 50 percent have infrastructural or technology benefits (increasing manmade capital).

Sources: Haites, Maosheng, and Seres 2006; Watson and Fankhauser 2008; Dechezlepretre and others 2008.

three gas-flaring projects in Nigeria. There is a similar concentration in sectors, with much of the abatement action concentrated in a fairly small number of industrial gas projects. The CDM has not supported any increased efficiencies in the built and household environments or transportation systems, which produce 30 percent of global carbon emissions[18] and are the fastest-growing sources of carbon emissions in the emerging markets.[19] Nor has the CDM supported sustainable livelihoods or catalyzed energy access for the rural and peri-urban poor.[20] The exclusion of deforestation emissions from the CDM leaves the largest emission source of many tropical developing countries untapped.[21]

Weakness of the incentive, reinforced by uncertainty about market continuity. The CDM has not moved developing countries onto low-carbon development paths.[22] The incentive of the CDM has been too weak to foster the necessary transformation in the economy, without which carbon intensities in developing countries will continue to increase.[23] The CDM's project approach structure and lack of leverage have restricted it to a fairly small number of projects. Uncertainty about the continuation of the carbon offset market beyond 2012 is also having a chilling effect on transactions.

The efficiency cost of adaptation funding

An important source of adaptation finance, and the key revenue source of the Adaptation Fund, is a 2 percent levy on the CDM, a tax that could be extended to include other trading schemes, such as Joint Implementation. This is a promising route to raising financial resources for the Adaptation Fund, which offers clear additionality. But it also raises some basic economic issues. Perhaps the most important objection is that the CDM levy is taxing a good (mitigation finance) rather than a bad (emissions). More generally, the levy raises two basic questions:

- What is the scope of raising additional adaptation finance through the levy, and

what is the loss in economic efficiency (or deadweight loss, in economic jargon) associated with the tax?
- How is the tax burden distributed between the sellers (developing countries) and buyers (developed countries)?

Analysis based on the U.K. government's GLOCAF model shows that the ability of an extended carbon trading scheme to raise additional adaptation revenues will depend on the type of global climate deal that is agreed.[24] Revenues will vary depending on the expected demand, particularly whether demand will be constrained by supplementary restrictions to promote domestic abatement, and to a lesser extent on the expected supply, including whether a future regime could encompass credits from avoided deforestation and from other sectors and regions that currently produce little carbon trade.

Revenues will also depend on the tax rate. At the current rate of 2 percent the levy could be expected to raise around $2 billion a year in 2020 if demand is unconstrained but less than half that amount if restrictions are placed on the purchase of credits (table 6.5). To raise $10 billion a year the tax rate would have to increase to 10 percent and all supplementary restrictions would have to be abolished. Even at this higher rate the economic cost of the tax would be fairly minor, particularly in relation to the overall gains from trade.

Like all taxes, the cost of the levy is shared between the buyers and sellers of carbon credits depending on their responsiveness to price changes (the price elasticities of supply and demand). In the scenarios where demand is constrained, buyers do not respond strongly to the tax, and much of the tax burden is thus passed on to them. But this response changes if constraints on demand are eased. At that point the tax incidence shifts decidedly against developing countries, which have to shoulder more than two-thirds of the tax burden to keep the price of their credits competitive. That is, developing countries would make the main contribution to the Adaptation Fund (through forgone carbon market revenues). Rather than transferring funds from developed to developing countries, the CDM levy would transfer resources from the big CDM host countries (Brazil, China, India —see table 6.3) to the vulnerable countries eligible for adaptation funding.

Increasing the scale of climate-change finance

To close the financing gap, financing sources have to be diversified, and the existing instruments have to be reformed to increase their efficiency and permit the required scale-up. This section highlights some of the main challenges in this respect, arguing for the following:

- Harnessing new sources of revenue to support adaptation and mitigation by national governments, international organizations, and dedicated financing mechanisms like the Adaptation Fund.
- Increasing the efficiency of carbon markets by reforming the CDM as a key vehicle to promote private mitigation funding.
- Expanding performance-based incentives to land use, land-use change, and forestry to change the balance between private and public funding in this important area.
- Leveraging private sector funding for adaptation.

Countries will also have to consider the fiscal framework for climate action. Government action on climate mitigation and adaptation can have important fiscal

Table 6.5 The tax incidence of an adaptation levy on the Clean Development Mechanism (2020)
$ millions

Tax rate	Revenue raised	Deadweight loss	Burden to developing countries
2 percent			
Restricted demand and low supply	996	1	249
Unrestricted demand and high supply	2,003	7	1,257
10 percent			
Restricted demand and low supply	4,946	20	869
Unrestricted demand and high supply	10,069	126	6,962

Source: Fankhauser, Martin, and Prichard 2009.

Note: Under restricted demand, regions can buy up to 20 percent of their target through credits; there is completely free trading in the unrestricted demand scenario. In the low-supply scenario the CDM operates in the same sectors and regions as it does now. In the high-supply scenario carbon trading is expanded in regional and sectoral scope, including credits from reduced emissions from deforestation and degradation (although, as noted, the latter emissions are not currently in the CDM). The total market volume (excluding secondary transactions) is around $50 billion in the restricted-demand, low-supply case and around $100 billion in the unrestricted-demand, high-supply case.

BOX 6.3 *Carbon taxes versus cap-and-trade*

The principal market-based instruments used for climate mitigation are carbon taxes and cap-and-trade schemes. By eschewing fixed quotas or technology standards (the usual regulatory instruments employed by governments), these instruments leave individual firms and households free to find the least-cost way to meet a climate target.

A carbon tax is a price instrument and typically operates by taxing the carbon content of fuel inputs, thus creating an incentive either to switch to lower-carbon fuels or to use fuel more efficiently. However, because governments have imperfect information about the costs of fuel switching or increasing energy efficiency, there is corresponding uncertainty about how much abatement will actually occur for a given tax level. If a government has an emission cap under a global agreement, then it may need to adjust the tax rate iteratively to keep emissions within the cap.

Under a cap-and-trade scheme, governments issue emission permits representing a legal right to emit carbon—these permits are freely tradable between scheme participants. Because firms and sectors will differ in their marginal costs of fuel switching or energy efficiency, the potential for gains from trade exists. For example, if one firm has a high marginal cost of mitigation while another has a much lower cost, then the firm with the lower cost can sell a permit at a price above its marginal cost of mitigation, reduce its emissions accordingly, and make a profit—and as long as the price of the permit is below the marginal mitigation cost of the buyer, then this is a profitable trade for the buyer as well. Because cap-and-trade is a quantitative instrument, there is high certainty that a country will stay within its cap (assuming that enforcement is effective), but there may be a corresponding uncertainty about the level and stability of permit prices.

The two instruments differ in important ways:

Efficiency

Because of imperfect information about mitigation costs, there is a risk with any market instrument of abating emissions, either too much or not enough, engendering either excess costs or excess damages. A famous result by Weitzman shows that the choice of instrument under uncertainty depends on the relative slope of the damage and abatement cost functions. What this means in the case of climate change is unclear, since the shape of the damage function is highly uncertain. However, because greenhouse gases are stock pollutants, many have argued that, in the short-term, damages are likely to be fairly constant per marginal ton, which would favor a tax.

Price volatility

While cap-and-trade creates certainty about the quantity of emissions, it may lead to uncertainty about price. For example, if there is a shift in the business cycle or in the relative prices of low-carbon and high-carbon fuels, then permit prices will be directly affected. Price volatility not only makes it difficult to plan abatement strategies, it also reduces the incentive to invest in research and development on new abatement technologies. Banking and borrowing of allowances are two simple mechanisms that can help dampen price volatility.

Recycling revenues

A carbon tax is a direct source of fiscal revenue, and governments have the option of either using the tax to finance expenditures or recycling the revenues by lowering or eliminating other taxes. To the extent that recycling increases the overall efficiency of the tax system, there is a "double dividend"—but a double dividend is not guaranteed if the carbon taxes themselves exacerbate existing inefficiencies in the tax system. If emission permits are auctioned by the government, then these too become a source of fiscal revenue.

Political economy

Because the world has a fixed carbon budget for any chosen climate target, the certainty associated with a quantitative instrument may be appealing to some groups. And everyone, whether firms or individuals, dislikes taxes. This line of reasoning may seem to favor cap-and-trade, but tax aversion also means that firms will resist auctioning of permits and may instead lobby for their allocation of free permits. In general the process of allocating permits, if not done through auction, leads to rent seeking and potentially corrupt behavior.

Administrative efficiency

The cost of administering climate policy and the institutional and human capital required are particularly important considerations in developing countries. A tax on the carbon content of fuels is potentially very cost-effective because it could piggyback on existing administrative systems for levying excise taxes on fuels. In contrast setting up a market for auctioning and trading permits could be highly complex, and a regulator would be required to monitor the exercise of market power by participants. In addition, a permit system would require monitoring and enforcement at the level of individual emitters, while monitoring of a carbon tax potentially could be done much more cheaply at the level of fuel wholesalers.

Carbon taxes and cap-and-trade are not necessarily mutually exclusive. The European Union has opted for emissions trading to address emissions from large sources (utilities, heat production, large energy-intensive industrial facilities, and aviation, to be phased in in 2011), covering about 40 percent of EU emissions. Other instruments (including a carbon tax in several European countries) target emissions from other sectors, notably residential and services, transport, waste management, and agriculture. In contrast in Australia and the United States cap-and-trade is emerging as the main instrument to regulate economywide greenhouse gas emissions (with a set of accompanying policies and measures, like renewable energy portfolio standards).

Sources: Bovenberg and Goulder 1996; Weitzman 1974; Aldy, Ley, and Parry 2008; Newell and Pizer 2000.

consequences for revenues, subsidies, and flows of international finance. Key elements of this framework include the following.

Choice of mitigation instrument. Taxes or tradable permits will be more efficient instruments than regulation, and each can generate significant fiscal revenues (assuming that permits are auctioned by the government). Box 6.3 highlights the key characteristics of carbon taxes versus cap-and-trade approaches.

Fiscal neutrality. Countries have the option of using carbon fiscal revenues to reduce other distorting taxes, which could have major growth and welfare consequences. But treasuries in developing countries typically have a weak revenue base, which may reduce the incentives for complete fiscal neutrality.

Administrative simplicity and cost. Carbon taxes, because they can be placed on the carbon content of fuels, offer the simplicity of building on existing fuel excise regimes. Cap-and-trade systems can entail large administrative costs for allocating permits and ensuring compliance.

Distributional impacts. Any price instrument for mitigation will have distributional consequences for different income groups depending on the carbon intensity of their consumption and whether they are employed in sectors that shrink as a result of carbon taxes or caps; offsetting fiscal actions may be required if low-income households are disproportionately affected.

Policy coherence. Existing subsidy schemes, particularly on energy and agriculture, may run counter to actions to mitigate and adapt to climate change. Subsidies on goods that will become scarcer under climate change, such as water, also risk perverse effects.

Box 6.4 highlights the efforts of the Indonesian Ministry of Finance to incorporate climate issues into overall macroeconomic and fiscal policy.

Generating new sources of finance for adaptation and mitigation

Public institutions—national governments, international organizations, and the official financing mechanisms of the UNFCCC—are among the key drivers of climate-smart

BOX 6.4 *Indonesian Ministry of Finance engagement on climate change issues*

Indonesia's Finance Ministry has recognized that mitigating and adapting to climate change require macroeconomic management, fiscal policy plans, revenue-raising alternatives, insurance markets, and long-term investment options. With development as the priority, Indonesia is trying to balance economic, social, and environmental goals. The country could benefit from investing in development with climate-friendly technology for a cleaner, more efficient growth path. Benefits would include potential payments from carbon markets for the reductions in emissions achieved from a cleaner energy path or from reductions in the annual rate of deforestation. The Ministry of Finance will play an essential role in the financing, development, and implementation of climate-change policies and programs. To mobilize the financing needed, Indonesia envisions a mix of mechanisms paired with integrated national policies, a strong enabling framework, and long-term incentives to attract investment.

The Finance Ministry's comparative advantage is in considering the allocation and incentive decisions that affect the whole economy. In managing climate-financing opportunities, the ministry acknowledges the importance of investor and donor confidence in its approaches and institutions. Recognizing that donor funds—whether grants or soft loans—will always be small relative to private investment in energy sector development, infrastructure, and housing, Indonesia will continue to need sound policies and incentives to attract and leverage private investment toward sustainable development and lower-carbon outcomes.

Indonesia has already taken steps to rationalize energy pricing by reducing fossil-fuel subsidies in 2005 and 2008, to reduce deforestation through improved enforcement and monitoring programs, and to provide incentives for import and installation of pollution control equipment through tax breaks. The Finance and Development Planning ministries have established a national blueprint and budget priorities for integrating climate change into the national development process. The Finance Ministry is examining fiscal and financial policies to stimulate climate-friendly investment, move toward lower-carbon energy options including renewables and geothermal, and improve fiscal incentives in the forestry sector.

Source: Ministry of Finance (Indonesia) 2008.

development. So far they have relied almost exclusively on government revenues to finance their activities. But it is unlikely that climate-change costs rising into the tens or hundreds of billions of dollars a year could be predominantly covered through government contributions. Although additional funds will be forthcoming, the experience with development assistance suggests that there are constraints on the amount of traditional donor finance that can be raised. Moreover, there is a worry from developing countries that contributions from developed countries may not be fully additional to existing development assistance.

Other sources of finance will therefore have to be tapped, and there are several proposals, particularly for adaptation. These include:

Internationally coordinated carbon tax. Proposals for a nationally administered but globally levied carbon tax have the appeal that the tax base would be broad and the revenue flow fairly secure. Moreover, unlike the CDM levy, the tax would be aimed at emissions rather than emission reductions. Rather than impose a deadweight loss, the tax would have a desirable and beneficial corrective effect. The main drawback is that an internationally coordinated tax could impinge on the tax authority of sovereign governments. Gaining international consensus for this option may thus be difficult.

Tax on emissions from international transport. A tax more narrowly focused on international aviation or shipping would have the advantage of targeting two sectors that so far have not been subject to carbon regulation and whose emissions are growing fast. The international nature of the sector might make a tax more palatable for national finance ministers, and the tax base would be large enough to raise considerable amounts. But the global governance of the sectors is complex, with considerable power in the hands of international bodies, such as the International Maritime Organization. So the administrative hurdles of setting up such a tax might be considerable.

Auctioning assigned amount units. The emission reduction commitments of parties under the Kyoto Protocol are expressed in assigned amount units (AAUs)—the amount of carbon a country is permitted to emit. An innovative approach, put forward originally by Norway, would set aside a fraction of each country's AAU allocation and auction it to the highest bidder, with revenues earmarked for adaptation.

Domestic auction revenues. Earmarking auction revenues relies on the assumption that most developed countries will soon have fairly comprehensive cap-and-trade schemes and that most of the permits issued under the schemes would be auctioned rather than handed out for free. With schemes already running or under consideration in practically all developed countries, this is a reasonable expectation. But earmarking auction revenues would encroach on the fiscal autonomy of national governments just as much as an internationally coordinated carbon tax and may therefore be similarly difficult to implement.

Each of these options has its advantages and disadvantages.[25] What is important is that the chosen options provide a secure, steady, and predictable stream of revenues of sufficient size. This suggests that finance will have to come from a combination of sources. Table 6.6 presents a range of potential sources of finance as proposed by developed and developing countries.

In the short term some impetus may also come from international efforts to overcome the current economic slump and kick-start the economy through a fiscal stimulus (see chapter 1).[26] Globally, well over $2 trillion has been committed in various fiscal packages, chief among them the $800 billion U.S. package and the $600 billion Chinese plan. Some 18 percent of this, or about $400 billion, is green investment in energy efficiency and renewable energy, and also, in the Chinese plan, adaptation.[27] Deployed over the next 12–18 months these investments could do much to shift the world toward a low-carbon future. At the same time, the packages are by their very nature geared toward stimulating domestic activity. Their effect on international climate finance to developing countries will at best be indirect.

Table 6.6 Potential sources of mitigation and adaptation finance

Proposal	Source of funding	Note	Annual funding ($ billions)
Group of 77 and China	0.25–0.5 percent of gross national product of Annex I Parties	Calculated for 2007 gross domestic product	201–402
Switzerland	$2 a ton of CO_2 with a basic tax exemption of 1.5 ton CO_2e per inhabitant	Annually (based on 2012 projections)	18.4
Norway	2 percent auctioning of AAUs	Annually	15–25
Mexico	Contributions based on GDP, greenhouse gases, and population and possibly auctioning permits in developed countries	Annually, scaling up as GDP and emissions rise	10
European Union	Continue 2 percent levy on share of proceeds from CDM	Ranging from low to high demand in 2020	0.2–0.68
Bangladesh, Pakistan	3–5 percent levy on share of proceeds from CDM	Ranging from low to high demand in 2020	0.3-1.7
Colombia, least developed countries	2 percent levy on share of proceeds from Joint Implementation and emissions trading	Annually, after 2012	0.03–2.25
Least developed countries	Levy on international air travel (IATAL)	Annually	4–10
Least developed countries	Levy on bunker fuels (IMERS)	Annually	4–15
Tuvalu	Auction of allowances for international aviation and marine emissions	Annually	28

Source: UNFCCC 2008a.

Note: AAU: assigned amount unit; IATAL: international air travel adaptation levy; IMERS: international maritime emission reduction scheme. Annex I Parties include the high-income countries that were members of the OECD in 1992, plus countries with economies in transition. Annex I countries have committed themselves specifically to the aim of returning individually or jointly.

It takes more than finance: Market solutions are essential but additional policy tools are needed

With more national or regional initiatives exploring emissions trading, the carbon market will likely be significant in catalyzing and financially supporting the needed transformation of investment patterns and lifestyles. Through purchasing offsets in developing countries, cap-and-trade systems can finance lower-carbon investments in developing countries. Carbon markets also provide an essential impetus to finding efficient solutions to the climate problem.

Looking forward, stabilizing temperatures will require a global mitigation effort. At that point carbon will have a price worldwide and will be traded, taxed, or regulated in all countries. Once an efficient carbon price is in place, market forces will direct most consumption and investment decisions toward low-carbon options. With global coverage many of the complications affecting the current carbon market—additionality, leakage, competitiveness, scale—will fall away. They matter enormously today, and in addressing them the need for a smooth transition to an ultimately global carbon market must not be forgotten. However, some market failures will remain, and governments will need to intervene to correct them.

Decisions that help the emergence of a long-term, predictable, and adequate carbon price are necessary for effective mitigation but, as chapter 4 shows, not sufficient. Some activities, such as risky research and development or energy-efficiency improvements, are hindered by market or regulatory failures; others, such as urban planning, are not directly price sensitive. The forest and agriculture sectors present significant additional potential for emission reduction and sequestration in developing countries but are too complex, with intricate social issues, to rely exclusively on market incentives. Many climate actions will require complementary finance and policy interventions—for example, to overcome energy-efficiency barriers, reduce perceived risks, deepen domestic financial and capital markets, and accelerate the diffusion of climate-friendly technologies.

Increasing the scale and efficiency of carbon markets

The absence of market continuity beyond 2012 is the biggest risk to the momentum of today's carbon market. Considerable uncertainties remain about the very existence of a global carbon market beyond 2012, with questions about the ambition of mitigation targets, the resulting demand for carbon credits, the degree of linking of different trading schemes, and the role for offsets across various existing and upcoming regimes. Defining a global mitigation goal for 2050 supported by intermediate targets (to be determined through the UNFCCC process) would provide long-term carbon price signals and certainty to the private sector as major investment decisions with long-lasting impact on emission trajectories are made over the coming years.

The next phase in constructing a global carbon market must put developed countries onto a low-carbon path and provide the financial and other resources needed to assist the transition of developing countries to a lower-carbon development path. One of the main challenges for a climate agreement is to define a framework that supports and promotes this transformation and facilitates the transition to a more comprehensive system where more countries assume emission reduction targets. As discussed in chapter 5, a gradual incorporation process can be envisaged, with transitions toward more stringent steps depending on responsibility and capacity: adopting climate-friendly policies (a stage many developing countries have already reached), limiting emissions growth, and setting emission reduction targets. To support this gradual progress, various models using carbon finance have been proposed.[28]

But demand for international offsets from Annex I countries will likely remain for quite some time at levels well below what would be needed to reward all mitigation achievements in developing countries while simultaneously maintaining a sufficiently high carbon price. Setting more ambitious targets for Annex I countries[29] will create the incentive for greater cooperation with developing countries in scaling up mitigation, provided a credible supply of offsets can be built at scale.

Concern about the effectiveness and efficiency of the CDM has led to a broad array of proposals on how to enhance, expand, or evolve the mechanism. Broadly speaking, these could be organized along two lines of suggestions. One track would aim at streamlining the CDM to make it more appropriate for a growing market dominated by the private sector by improving efficiency and governance along the project cycle as well as by reducing transaction costs. Another track would aim at scaling up the transformational impact of CDM and carbon finance beyond the limited scope of a project approach, focusing on investment trajectories and affecting emission trends.

It is probably not realistic to attain anything more than incremental changes to the CDM by 2012. Some practitioners clamor for big improvements. But many countries are still learning the ropes of the instrument, and their first projects just began to enter the pipeline in the past few months. Others are focused on the agreement and tools for scaling up post-2012 mitigation. There is little or no political space to undertake immediate major revisions to the CDM before 2012, a point emphasized by developing countries that have argued that most of those revisions would require an amendment to the Kyoto Protocol. So, to organize the steps in a possible evolution, it may help to distinguish two levels of improvements or changes to the current CDM, which would ultimately result in two financial mechanisms, operating in parallel and complemented by a nonmarket mechanism funded by public sources.

An activity-based CDM. There is a case to continue operating the current activity-based CDM within its existing rules, with some targeted improvements. In the current system the baseline and additionality are determined for the individual project activity, and the rules seek to differentiate and reward individual efforts that are better than the norm (rather than promoting a better norm). Most medium-to-large installations in small countries can be effectively submitted as individual CDM projects, and microtechnologies such as light bulbs and cooking stoves now have the option of being registered as organized programs of activities under the current CDM (thus cutting down on transaction costs through aggregation). Most small or least developed countries have more urgent demands on scarce institutional capacity than the development of complex greenhouse gas accounting schemes. This means that for some developing countries, perhaps most, there is no need for another set of rules to supply their mitigation potential into the market.

Key administrative improvements would target, for example, improving the quality, relevance, and consistency of information flows within the CDM community; engagement of a professional, full-time staff for the CDM Executive Board and consideration of how to make it more representative of practitioners; and development of ways to increase the accountability of the process, potentially including a mechanism that provides an opportunity for project participants to appeal board decisions. In parallel, countries would have to create a business environment conducive to low-carbon investment in general.

A trend-changing market mechanism. This new mechanism would seek to reduce long-term emission trends much more comprehensively. Set up either in or outside the current CDM, it would support the enactment of policy changes that put developing countries onto a low-carbon path. It would recognize and promote emission reductions achieved by adopting particular policies or programs that lead to emission reductions at multiple sources. A programmatic CDM could be a first step toward a trend-changing market mechanism, allowing for the aggregation of unlimited similar activities resulting from the implementation of a policy across time and space. Proposals to support a sectoral shift can be classified in two broad groups: those that stem from an agreement among industries that operate in the same sector but are located across different countries; and those that evolve from a national government's decision to implement a specific policy or program.

There have been many thoughts on how CDM and carbon finance could support climate-friendly policies in developing countries. The proposed options all consider a mechanism for carbon finance to reward the measurable outcomes of a policy (in reduced emissions). Variants pertain to the policy and country commitment under an international agreement (mandatory or flexible), the geographical scale (regional or national), or the sectoral scope (sectoral or cross-sectoral). Among these options sectoral no-lose targets, whereby a country could sell carbon credits for emission reductions below an agreed target (which would lie below business-as-usual levels), while not being penalized for not achieving the target, have attracted a great deal of interest. Such a mechanism would be adapted to developing countries needing to significantly scale up private sector investment—beyond the reach of the CDM in its current form—in line with their sustainable development priorities.

Creating financial incentives for REDD

A particular concern for developing countries is the lack of financial incentives for reduced emissions from deforestation and forest degradation (REDD). In 2005, nearly one fourth of emissions in developing countries came from land-use change and forestry, so this is a substantial exclusion.[30] But land use, land-use change, and forestry have always been problematic and contentious in the climate negotiations. There was great opposition to their inclusion in the Kyoto Protocol. As a result,

Table 6.7 National and multilateral initiatives to reduce deforestation and degradation

Initiative	Total estimated funding ($ millions)	Period
International Forest Carbon Initiative (Australia)	160	2007–12
Climate and Forest Initiative (Norway)	2,250	2008–12
Forest Carbon Partnership Facility (World Bank)	300	2008–18
Forest Investment Program (part of Climate Investment Funds)	350	2009–12
UN-REDD Program	35	2008–12
Amazon Fund	1,000	2008–15
Congo Basin Forest Fund	200	Uncertain

Source: UNFCCC 2008b.
Note: Names in parentheses are countries or institutions that championed the proposal.

BOX 6.5 *Conserving agricultural soil carbon*

The mitigation potential in the agricultural sector could be significant, estimated to be around 6 gigatons of carbon dioxide equivalent (CO_2e) a year by 2030, with soil carbon sequestration being the main mechanism. Many mitigation opportunities (including cropland management, grazing land management, management of organic soils, restoration of degraded land, and livestock management) use current technologies and can be implemented immediately. In addition, these options are also cost competitive: assuming a price of less than $20 a ton of CO_2e, the global economic mitigation potential in the agricultural sector is close to 2 gigatons of CO_2e a year by 2030.

Extending the scope of carbon markets to include agricultural soil carbon would allow carbon finance to play more of a role in sound land management practices. Agricultural carbon sequestration can help increase agricultural productivity and enhance farmers' capacity to adapt to climate change. Increased soil carbon improves soil structure, with corresponding reduction in soil erosion and nutrient depletion. Soils with increased carbon stocks retain water better, thereby improving the resilience of agricultural systems to drought. These positive biophysical impacts of soil carbon sequestration lead directly to increased crop, forage, and plantation yields and land productivity. However, issues of monitoring and verification of the increased storage and the permanence of the carbon sequestration need to be resolved.

Source: IPCC 2007.

only afforestation and reforestation were allowed within the CDM, but the European Union Emission Trading Scheme excludes them.

Initial attention to REDD was focused on countries where deforestation is occurring (table 6.7). But some heavily forested countries have little deforestation, and they seek support to manage and conserve their forests sustainably, especially if REDD activities in other countries shift logging and agricultural expansion across national borders (leakage). Other countries already have policies and measures to bring their forests under sustainable management, and they seek recognition of their efforts in reducing emissions through market-based solutions akin to payments for environmental services. As discussed in chapter 3, conserving soil carbon (box 6.5) through performance-based mechanisms is also gaining traction, but discussions are at a less advanced stage than for REDD.

REDD touches on many groups and other societal goals, often with a mix of potential positive and negative effects. It could provide a new source of income to indigenous peoples, but they are rightly concerned that REDD mechanisms may be used to threaten their rights of access and their use of traditional lands. REDD may provide resources to bring areas of high biodiversity value under better protection, but it could also displace logging and land clearing across international borders to high biodiversity areas (another example of leakage).

It is generally recognized that before forest countries can receive financial incentives for REDD, they need to establish building blocks in the policy, legal, institutional, and technical areas—referred to as REDD-readiness. The key components of REDD-readiness ought to be carried out at the national level (not at the project level) to respond to the systemic causes of deforestation and forest degradation and to contain leakage.

The Forest Carbon Partnership Facility (FCPF) has been designed to help forest countries in tropical and subtropical regions prepare for REDD and pilot performance-based incentives. In the FCPF, REDD-readiness consists of a national REDD strategy and implementation framework; a national reference scenario for emissions from deforestation and forest degradation; and a national monitoring, reporting, and verification system. The UN-REDD, a joint initiative of the Food and Agriculture Organization, the United Nations Development Programme, and the United Nations Environment Programme, is a similar program.

In its national REDD strategy a country would assess its land use and forest policy to date, identifying the drivers of deforestation and forest degradation. Next, it would conceive strategic options to address these drivers and would assess these options from the point of view of cost-effectiveness, fairness, and sustainability. This would be followed by an assessment of the legal and institutional arrangements needed to implement the REDD strategy, including the body (or bodies) responsible for coordinating REDD at the national level, promoting REDD, and raising funds; benefit-sharing mechanisms for the financial flows expected from REDD; and a national carbon registry to manage REDD activities (both the emission reductions generated and the corresponding revenue flows). In addition, the country would evaluate the investment and capacity building needed to implement the strategy and would assess the environmental and social impacts of the various strategy and implementation options (the benefits, risks, and risk-mitigation measures).

REDD-ready countries need to develop a national reference scenario. The scenario should include a retrospective part, calculating a recent historical average of emissions, and could also include a forward-looking component, forecasting future emissions based on economic growth trends and national development plans.

A national monitoring, reporting, and verification (MRV) system is central to a system of performance-based payments. The MRV system could include the payments' impacts on biodiversity and livelihoods as well as on carbon levels. The roles of remote-sensing technology and ground-based measurements must be defined as part of the MRV system. Experience from community-based natural resource management initiatives has shown that involvement of local people, including indigenous peoples, in participatory monitoring of natural resources can also provide accurate, cost-effective, and locally anchored information on forest biomass and natural resource trends.[31] Natural resource stocks, benefit sharing, and wider social and ecological effects of REDD schemes can be monitored by local communities. Participatory approaches have the potential to greatly improve the governance and management of REDD schemes.

Before large-scale, performance-based payments for REDD can begin, most forest countries will need to adopt policy reforms and undertake investment programs. Investments may be needed to build institutional capacity, improve forest governance and information, scale up conservation and sustainable management of forests, and relieve pressure on forests through, say, relocating agribusiness activities away from forests or improving agricultural productivity. To assist countries in these activities several initiatives have been launched or are under design (see table 6.7). In addition the World Bank has proposed a forest investment program under the Climate Investment Funds, and the Prince's Rainforest Project and the Coalition for Rainforest Nations have recently proposed that financial institutions issue bonds to raise significant resources to help forest countries finance forest conservation and development programs. This example illustrates how a mix of instruments is required to steer a transformation of behaviors and investment decisions: a combination of up-front finance (concessional and innovative finance) and performance-based incentives are needed to promote policy reforms, build capacity, and undertake investment programs. The example also highlights the crucial role of public finance as a catalyst for climate action.

Leveraging private finance for adaptation

Compared with mitigation, where the emphasis has been on private finance from carbon markets, adaptation finance has a strong focus on official flows. This is not surprising, given that adaptation is closely linked to good development and that many adaptation measures are public goods—for example, the protection of coastal zones (a local public good) and the provision of timely climate information (a national public good).

Despite the emphasis on public finance, much of the adaptation burden will fall on individuals and firms. Insurance against climate hazards, for example, is provided primarily by the private sector. Similarly, the task of climate-proofing the world's capital stock—private dwellings, factory buildings, and machinery—will fall predominantly on private owners, although the state will have to provide flood protection and disaster relief. Private companies also own or operate some of the public infrastructure that will have to be adapted to a warmer world—seaports, electric power plants, and water and sewage systems.

For governments the challenge of involving the private sector in adaptation finance is threefold: getting private players to adapt; sharing the cost of adapting public infrastructure; and leveraging private finance to fund dedicated adaptation investments.

Getting private players to adapt effectively. Most consumption and business decisions are affected, directly or indirectly, by climate factors—from the clothes people wear to the planting decisions farmers make to the way buildings are designed. People are used to making these implicit adaptation decisions. The main role for governments will be to provide an economic environment that facilitates these decisions. This can take the form of economic incentives (tax breaks for adaptation investments, property taxes differentiated by risk, differentiated insurance premiums), regulation (zone planning, building codes) or simply education and better information (long-term weather forecasts, agricultural extension services).

These measures will entail an economic cost, such as meeting stricter building regulation, using different seed varieties, or paying higher insurance premiums. That cost will be borne by the economy and spread across sectors as producers pass on higher costs to their clients and as insurance schemes help to pool risks. There will be little need to draw on dedicated adaptation funding, except perhaps to meet the government's administrative costs or to protect vulnerable groups from the adverse effects of a policy.

Sharing the costs of adapting public infrastructure. A large part of the public adaptation bill involves climate-proofing a country's transport infrastructure, electric power networks, water systems, and communication networks. Whether these services are provided by public, private, or commercialized public entities, the bill will need to be funded either by taxpayers (domestic, or foreign if adaptation assistance is provided) or by users (through higher tariffs).

For infrastructure service providers climate change (and climate policy) will become another risk factor to take into account alongside other regulatory, commercial, and macroeconomic risks.[32] It would therefore be wise to build responsibility for adaptation into the regulatory regime as early and predictably as possible. The greater physical uncertainty also requires building more flexibility into the regulatory system because ex ante regulation is ill suited to situations with unpredictable changes. New and innovative approaches to regulation offer promising alternatives. A good example is the model adopted by the U.K. energy regulator, which can act as an auditor and leave investment decisions to the key actors in the government and the private sector.[33]

Leveraging private finance to fund dedicated adaptation investments. For several reasons the scope for private participation in dedicated adaptation infrastructure is probably limited. Given that dedicated adaptation investments typically do not create commercial revenues for private operators, they must be remunerated from the public purse. This creates a debt-like liability for the government that needs to be recorded in the public accounts. Nor does the efficiency argument look compelling.[34] Adaptation structures such as flood defenses are fairly cheap and simple to operate and so offer little scope for operational efficiency gains by a private manager. There may be more scope for efficiency gains in the construction and design phase, but these can be captured equally well through appropriate procurement mechanisms.

More generally private flows have amounted to a small share of the overall infrastructure funding needs of developing countries and are likely to remain modest for the duration of the current financial crisis.[35] For this and the reasons discussed above, infrastructure experts have warned not to expect too much from public-private partnerships in raising climate-change finance.[36]

Ensuring the transparent, efficient, and equitable use of funds

However successful the attempts at raising additional funds may be, climate finance will be scarce, so funds have to be used effectively and allocated transparently and equitably.

On the mitigation side, fund allocation will be dominated by efficiency considerations. Mitigation is a global public good, and its benefits are the same wherever abatement takes place (although the allocation of mitigation costs raises equity issues). With the right framework in place—essentially a carbon market that allows the exploration of abatement opportunities on a global scale while protecting host-country interests—a combination of carbon markets, other performance-based systems, and public funds aimed at niches overlooked by the market can allocate capital fairly effectively.

The allocation of adaptation finance, by contrast, raises important questions of fairness as well as efficiency. Unlike that for mitigation the allocation of adaptation resources has strong distributional implications. Money spent protecting small island states is no longer available for African farmers. The question of how to classify adaptation finance is still debated, and the controversy spills over to how to allocate this finance. Developing countries are inclined to view adaptation finance as compensation for damages, invoking a global polluter-pays principle. From the developing-country viewpoint, therefore, the question of how adaptation finance is used is beyond the purview of high-income countries. But the latter countries feel strongly that scarce financial resources should be used efficiently, whatever the justification for or provenance of the funds.

It can certainly be argued that the efficient and equitable allocation and use of adaptation finance are in everybody's interest. Wasteful use of resources can undermine public support for the whole climate agenda. That makes the transparent, efficient, and equitable allocation of adaptation funding paramount. As an example of how development institutions have handled the allocation of finance, consider the approach taken by the International Development Association (IDA), which constructs an index combining the need for finance, the absorptive capacity of the government, and the performance of the central government (box 6.6). The IDA approach is not without its faults. Because the formula is uniform across countries, it essentially imposes the same development model on all countries.[37] This is already problematic for standard development issues and may be even more so for climate change, where much less is known about the right adaptation model. Even so, an empirical approach to allocating adaptation finance that aims to address these concerns could serve at least three purposes: it could reduce transaction costs if lobbying and negotiation are not part of the allocation process; it could support the results agenda with an allocation process based on empirical measures; and it could support mutual accountability through transparency in allocations.

The measure of need for finance should be closely related to the concept of climate vulnerability. As conceived by the IPCC, vulnerability can be measured as the product of the capacity to adapt, the sensitivity to climate factors, and the exposure to climate change.[38] The measure of need for finance could thus be some population-weighted index of sensitivity and exposure, perhaps with a poverty weight as well. For large countries in particular, the distribution of impacts and differences in vulnerability between localities would also have to be taken into account.

BOX 6.6 *Allocating concessional development finance*

The International Development Association (IDA) allocation formula offers a possible model for allocating concessional finance in a transparent and empirically driven way. This evolving model of resource allocation, with 10 years of progressive refinement, has allocated roughly $10 billion of concessional finance a year to the world's poorest countries.

The IDA allocation formula breaks down into three basic indexes, one of *need* for concessional finance, one of *absorptive capacity,* and one of *performance of the central government*. On need, the basic criterion is the average poverty level in each country, weighted to favor the poorest countries, times the number of people in the country. Absorptive capacity is measured by World Bank portfolio performance—delays in disbursement and cancellations of loans or credits are clear indicators of poor ability to absorb additional finance. Based on results from the aid-effectiveness literature, the formula is weighted toward countries with the strongest governance because the evidence suggests that these countries most successfully translate aid resources into economic growth. Performance of central government in turn has two subindexes: *quality of macroeconomic, structural, and social policies and institutions* and *quality of governance*, derived from the World Bank Country Policy and Institutional Assessment.

The formula gives weights of 68 percent to governance; 24 percent to macroeconomic, social, and structural policies; and 8 percent to absorptive capacity. The composite of these scores is then multiplied by the number of people in the country, weighted by the average income of the population (to capture need) to derive the final score that drives the allocation of concessional finance.

Because this formula could penalize some of the neediest countries, a portion of the annual supply of finance is allocated off the top: each country receives a minimum allocation; countries coming out of conflict and with extremely fragile institutions are given additional assistance; and allowance is made for natural disasters. In addition IDA finance is capped for "blend" countries, which have access to commercial finance.

Sources: IDA 2007; Burnside and Dollar 2000.

Central government performance and absorptive capacity for flows of finance clearly determine a country's capacity to adapt, but they are not the only critical performance factors in climate adaptation. What might be called "social capacity" would appear important in determining the severity of local climatic impacts, including such factors as inequality (Gini coefficient), depth of financial markets, dependency ratio, adult literacy rate, and female education.

In sum, an allocation index for adaptation finance could consist of the following factors:

Allocation index = Central government performance
× Absorptive capacity
× Social capacity
× Climate sensitivity
× Climate change exposure
× Population weight
× Poverty weight

Actually constructing such an index presents several challenges. Information about the vulnerability of developing countries is still sketchy. Difficulties emerge from the complicated, and often undefined, pathways that translate potential impacts, themselves uncertain, into vulnerability. Compounding the uncertainty in linking environmental to socioeconomic impacts is the further uncertainty inherent in future climate scenarios. Models rely on a limited number of defined socioeconomic predictions, and each model has a range of potential changes. So most studies relating to future climatic scenarios focus on expected impacts within sectors or relate to specific outcomes, such as changes in health and losses because of sea-level rise. Few studies have attempted to translate these outputs into an assessment of vulnerability on the ground.[39]

As with IDA allocations, there is a risk that a climate adaptation allocation index will penalize poor countries with high climate sensitivity and exposure but very weak institutions. If an allocation formula is pursued, allowances for extremely fragile countries should be part of the overall allocation framework.

Some tentative first steps toward constructing a vulnerability index are shown in box 6.7, which plots a composite indicator of vulnerability to physical impact against a composite indicator of social capacity. The results of this stylized exercise are indicative only, but they suggest that the countries with the highest vulnerability are predominantly in Sub-Saharan Africa.[40] Box 6.8 scatters the same impact vulnerability index against a measure of country performance (combined central government capacity and ability to absorb finance) derived from the IDA allocation formula. Again Sub-Saharan Africa exhibits the combination of high vulnerability and low capacity to adapt.

Matching financing needs and sources of funds

Combating climate change is a massive socioeconomic, technological, institutional, and policy challenge. Particularly for developing countries it is also a financing challenge. By about 2030 the incremental investment needs for mitigation in developing countries could be $400 billion a year. The financing needs for adaptation by that time could be $75 billion a year. This is additional funding beyond baseline development finance needs, which also remain essential and will help in part to close existing adaptation gaps.

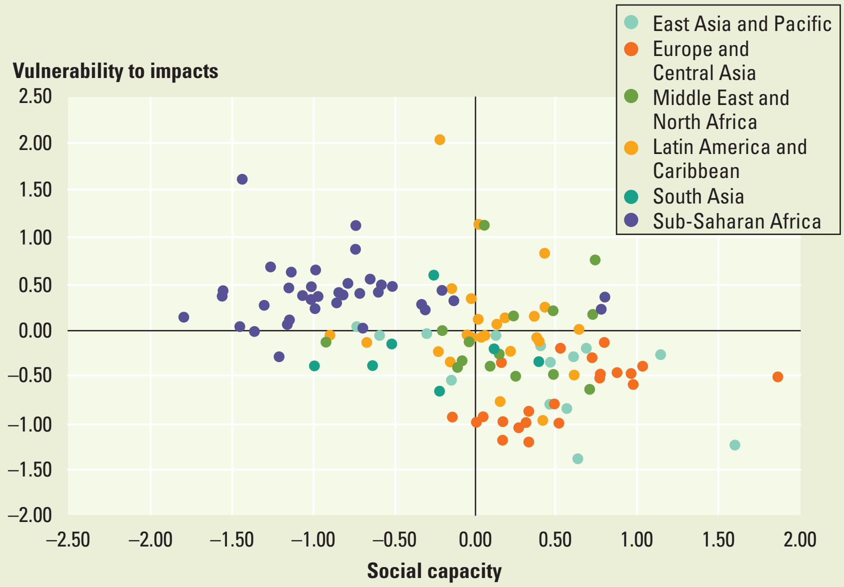
Though growing, current climate-related financial flows to developing countries cover only a tiny fraction of the estimated needs. No single source will provide that much additional revenue, and so a combination of funding sources will be required. For adaptation funding might come from the current adaptation levy on the CDM, which could raise around $2 billion a year by 2020 if extended to a wider set of carbon transactions. Proposals like the sale of AAUs, a levy on international transport emissions, and a global carbon tax could each raise around $15 billion a year.

For mitigation at the national level the majority of funding will have to come from the private sector. But public policy will need to create a business environment conducive to low-carbon investment, including but not limited to an expanded,

BOX 6.7 *Climate vulnerability versus social capacity*

The figure plots a composite indicator of physical impact (taken as a function of climate sensitivity and climate-change exposure and derived from a number of global impact studies) against a composite indicator of social capacity (derived from a number of socioeconomic indicators).

Social capacity and impact vulnerability are composites of the indexes described in the table below:



	Indicator	Metric	Source	Assumptions
Impact	Sea-level rise	Percent population affected, by 1 meter rise	Dasgupta and others 2007	Landlocked countries assumed to experience zero impact
	Agriculture	Percent yield loss in 2050, IPCC scenario A2b	Parry and others 2004	Decreasing yields represent decreasing welfare for country. Increased yields from climate change represent increasing welfare. Farm-level adaptation present
	Health	Percent additional deaths in 2050	Bosello, Roson, and Tol 2006	Additional deaths representative of all health impacts from climate change
	Disaster	Percent population killed by disasters (historical data set)	CRED 2008	Current disaster patterns to represent future areas at risk
Social capacity	Literacy	Percent population, aged >15 years, literate (1991–2005)	World Bank 2007c	The higher the literacy rate, the higher the social capacity
	Age dependency ratio	Ratio of dependent population to working population (2006)	World Bank 2007c	The lower the age dependency ratio, the higher the social capacity
	Primary completion rate (female)	Percent female population completing primary education (1991–2006)	World Bank 2007c	The higher the completion rate, the higher the social capacity
	Gini	Gini coefficient (latest available year)	World Bank 2007c	The lower the inequality, the higher the social capacity
	Domestic credit to private sector	Domestic credit to private sector, as percent of GDP (1998–2006)	World Bank 2007c	The greater the investment, the higher the social capacity
	Governance	WGI (World Governance Indicator) voice and accountability	Kaufman, Kraay, and Mastruzzi 2008	The higher the WGI score, the higher the social capacity

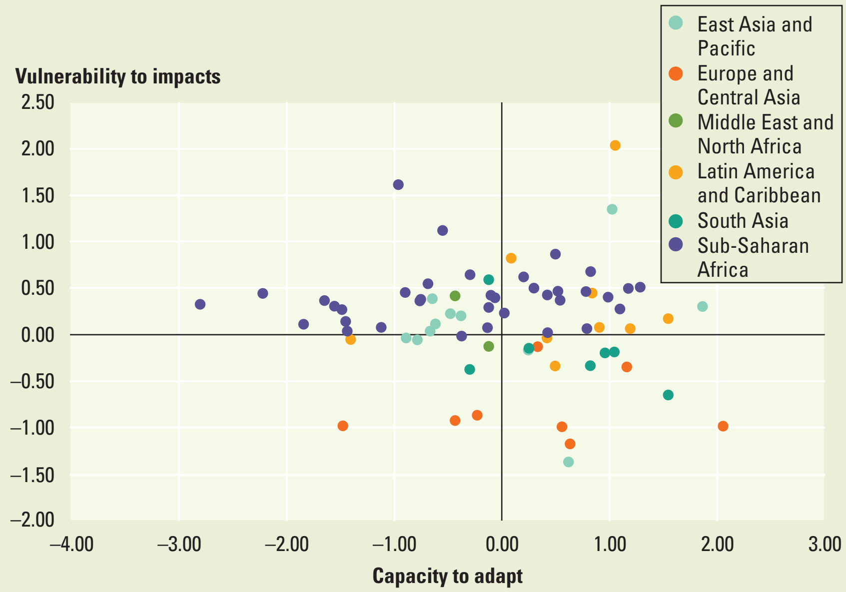
BOX 6.8 *Climate vulnerability versus capacity to adapt*

The figure plots the vulnerability index against a measure of country performance (combined central government capacity and ability to absorb finance) derived from the International Development Association allocation formula.

Capacity to adapt is a composite of indexes described in the table below, and it is calculated by the formula:

Country performance = 0.24*average (*CPIAa, CPIAb and CPIAc*) + 0.68**CPIAd* + 0.08**ARPP*,

Where CPIA = Country Policy and Institutional Assessment and ARPP = Annual Report on Portfolio Performance.



	Indicator	Metric (year)	Source	Assumptions
Capacity to adapt	Economic management	CPIAa (2007)	World Bank	The higher the country performance, the higher the capacity to adapt
	Structural policies	CPIAb (2007)	World Bank	
	Policies for social inclusion and equity	CPIAc (2007)	World Bank	
	Public sector management and institutions (governance)	CPIAd (2007)	World Bank	
	Capacity to absorb finance	ARPP (2007) World Bank portfolio at risk (age-discounted)	World Bank	

Sources: CPIA figures http://go.worldbank.org/S2THWI1X60. For details on the calculation of CPIA scores, see World Bank 2007b. ARPP scores are reported in World Bank 2007a.

efficient, and well-regulated carbon market. Complementary public funding—most likely from fiscal transfers—may be required to overcome investment barriers (such as those related to risk) and to reach areas the private sector is likely to neglect. Stringent emission targets will also be required—initially in high-income countries, eventually for many others—to create enough demand for offsets and to support the carbon price.

Once the majority of countries have emission caps under an international climate agreement, markets can autonomously generate much of the needed national mitigation finance as consumption and production decisions respond to carbon prices, whether through taxes or cap-and-trade. But national carbon markets will not automatically generate international flows of finance. Flows of mitigation finance to developing countries can come from fiscal flows, from linking national emission trading schemes, or potentially from trading AAUs. Flows from developed to developing countries can thus be achieved in several ways. But these flows are central to ensuring that an effective and efficient solution to the climate problem is also an equitable solution.

Notes

1. See the overview chapter for details.

2. Barker and others 2007.

3. For example, McKinsey Global Institute (2009) reports global abatement costs of $250 billion to $440 billion by 2030. The incremental capital costs associated with this program are in excess of $1 trillion, of which some $800 billion is in developing countries.

4. UNFCCC 2008a.

5. Agrawala and Fankhauser (2008) review the adaptation cost literature; Klein and Persson (2008) discuss the link between adaptation and development. Parry and others (2009) critique the UNFCCC adaptation cost estimate, suggesting that the true costs could be 2–3 times higher.

6. Besides carbon markets, tradable green and white certificates schemes (targeting respectively the expansion of renewable energy sources or the improvement of energy efficiency through demand-side management measures) are other examples of market-based mechanisms with potential mitigation benefits. Other instruments include financial incentives (taxes or subsidies, price support, tax benefits on investment, or subsidized loans) and other policy and measures (norms, labels).

7. The financial benefit to host countries is lower than the overall size of the CDM market for two reasons. First a vast majority of CDM transactions on the primary market are forward purchase agreements with payment on delivery of emission reductions. Depending on project performance, the amount and schedule of carbon delivery may prove quite different. Project developers tend to sell forward credits at a discount that reflects these delivery risks. Second CDM credits are bought and sold several times on a secondary market until they reach the end user. The financial intermediaries active on the secondary market that take on the delivery risk are compensated with a higher sell-on price if the risk does not materialize. These trades do not directly give rise to emission reductions, unlike transactions in the primary market. The secondary CDM market continued to grow in 2008 with transactions in excess of $26 billion (a fivefold increase over 2007). In contrast the primary CDM market declined in value for the first time, to $ 7.2 billion (down 12 percent from 2007 levels), under the weight of the economic downturn and amid lingering uncertainty about market continuity after 2012. See Capoor and Ambrosi 2008.

8. OECD/DAC, Rio Marker for climate change, http://www.oecd.org/document/11/0,3343,en_2649_34469_11396811_1_1_1_1,00.html (accessed May 2009).

9. UNEP 2009. Estimates of clean energy investments that benefit from CDM tend to be higher than actual sustainable energy investment in developing countries because many CDM projects are at an early stage (not operational or commissioned or at financial closure) when certified emission reductions are transacted.

10. See Decision 1/CP.13 reached at the 13th Conference of the Parties of the UNFCCC in Bali, December 2007, http://unfccc.int/resource/docs/2007/cop13/eng/06a01.pdf#page=3 (accessed July 3, 2009).

11. Michaelowa and Pallav (2007) and Schneider (2007), for example, claim that a number of projects would have happened anyway. In contrast, business organizations complain about an excessively stringent additionality test (IETA 2008; UNFCCC 2007).

12. Olsen 2007; Sutter and Parreno 2007; Olsen and Fenhann 2008; Nussbaumer 2009.

13. Cosbey and others 2005; Brown and others 2004; Michaelowa and Umamaheswaran 2006.

14. Streck and Chagas 2007; Meijer 2007; Streck and Lin 2008.

15. IETA 2005; Stehr 2008.

16. IETA 2008.

"The Ice is melting because of rising temperature. The boy sits upset. A bird has fallen—another victim of polluted air. Flowers grow near the trash can. They die before the boy could take them to the bird. To reverse these phenomena my appeal to world leaders is keep nature clean, use solar and wind energies, and improve technologies."

Shant Hakobyan, Armenia, age 12

17. Michaelowa and Pallav 2007; IETA 2008.
18. Barker and others 2007.
19. Sperling and Salon 2002.
20. Figueres and Newcombe 2007.
21. Eliasch 2008.
22. Figueres, Haites, and Hoyt 2005; Wara 2007; Wara and Victor 2008.
23. Sterk 2008.
24. See Fankhauser, Martin, and Prichard 2009.
25. See Müller 2008 for a discussion.
26. Barbier 2009; Bowen and others 2009.
27. Robins, Clover, and Magness 2009, as discussed in chapter 1.
28. These include models under which emission reductions would be rewarded in relation to particular sectors or that are built on various forms of targets, such as intensity or absolute or relative emission reduction. Crediting achievements could take place on the national level only or involve project activities. Crediting could be based on an initial allocation of allowances (cap-and-trade) or ex post (baseline-and-credit). And it could be linked or separated from existing carbon markets. Mechanisms that build on emissions trading can be directly or indirectly linked to other carbon markets and can create credits that are fully, partly, or not fungible with existing carbon markets.
29. If achieved, the total reductions of the various proposals of high-income countries would reduce emissions in aggregate only 10–15 percent below 1990 emissions levels by 2020. This is far short of the 25–40 percent reductions below 1990 levels that have been called for by the IPCC in the 2020 time frame; see Howes 2009.
30. WRI 2008; Houghton 2009.
31. Danielsen and others 2009.
32. Vagliasindi 2008.
33. Pollitt 2008.
34. Agrawala and Fankhauser 2008.
35. Investment commitments through public-private partnerships have amounted to 0.3–0.4 percent of developing countries' GDP over the 2005–07 period (Private Participation in Infrastructure Database, http://ppi.worldbank.org/). In contrast, infrastructure investment needs are estimated to range from 2 percent to 7 percent of GDP, with fast-growing countries like China and Vietnam investing upward of 7 percent of GDP a year. Estache and Fay 2007.
36. Estache 2008.
37. Kanbur 2005.
38. Füssel 2007.
39. Impact and vulnerability studies include, for instance, Bättig, Wild, and Imboden (2007); Deressa, Hassan, and Ringler (2008); Diffenbaugh and others (2007); and Giorgi (2006). Other studies have focused on sectoral losses or case study/country specific vulnerability: see Dasgupta and others (2007) on coastal zones; Parry and others (1999) and Parry and others (2004) on changes in global agricultural yields; Arnell (2004) and Alcamo and Henrichs (2002) for water availability changes; Tol, Ebi, and Yohe (2006) and Bosello, Roson, and Tol (2006) for health.
40. In boxes 6.7 and 6.8, composite indicators are calculated by transforming individual indicators to *z*-scores then taking an unweighted average of the resulting scores.

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will have a key role in financing mitigation through carbon markets and related instruments. But official flows or other international funding will be an important complement to build capacity, correct market imperfections, and target areas overlooked by the market. Private finance will also be important for adaptation, because private agents—households and firms—will carry much of the adaptation burden. But good adaptation is very closely linked to good development, and those most in need of adaptation assistance are the poor and disadvantaged in the developing world. This means public finance will have a key role.

In addition to raising new funds, using available resources more effectively will be crucial. This calls both for exploiting synergies with existing financial flows, including development assistance, and for coordinating implementation. The scale of the financing gaps, the diversity of needs, and differences in national circumstances require a broad range of instruments. Concerns with effectiveness and efficiency mean that finance for climate change must be raised and spent coherently.

Financing needs are linked to the scope and timing of any international agreement on climate change. The size of the adaptation bill will depend directly on the effectiveness of the agreement. For mitigation, chapter 1 shows that delayed implementation of emission reductions, whether in developed or developing countries, risks hugely increasing the cost of stabilizing the climate. The overview chapter shows that on a global least-cost path for climate stabilization, a large fraction (65 percent or more)[1] of the needed mitigation would occur in developing countries. The cost of stabilizing the climate can thus be substantially reduced if developed countries provide enough financial incentives for developing countries to switch to lower carbon paths. As other chapters emphasize, however, finance will need to be combined with access to technology and capacity building if developing countries are to shift to a lower-carbon development path.

This chapter deals with raising enough finance to reduce emissions and cope with the impacts of unavoidable changes. It assesses the gap between the projected needs for mitigation and adaptation finance compared with sources of finance available up to 2012. It looks at inefficiencies in the existing climate-finance instruments and discusses potential funding sources beyond the ones curently available (table 6.1). And it presents models for increasing the effectiveness of existing schemes, particularly the Clean Development Mechanism, and for allocating adaptation finance. Throughout the focus is on financing needs in developing countries,

Table 6.1 Existing instruments of climate finance

Type of instrument	Mitigation	Adaptation	Research, development, and diffusion
Market-based mechanisms to lower the costs of climate action and create incentives	Emissions trading (CDM, JI, voluntary), tradable renewable energy certificates, debt instruments (bonds)	Insurance (pools, indexes, weather derivatives, catastrophe bonds), payment for ecosystem services, debt instruments (bonds)	
Grant resources and concessional finance (levies and contributions including official development assistance and philanthropy) to pilot new tools, scale up and catalyze action, and act as seed money to leverage the private sector.	GEF, CTF, UN-REDD, FIP, FCPF	Adaptation Fund, GEF, LDCF, SCCF, PPCR and other bilateral and multilateral funds	GEF, GEF/IFC Earth Fund, GEEREF
Other instruments	Fiscal incentives (tax benefits on investments, subsidized loans, targeted tax or subsidies, export credits), norms and standards (including labels), inducement prizes and advanced market commitments, and trade and technology agreements		

Source: WDR Team.

Note: CDM = Clean Development Mechanism; CTF = Clean Technology Fund; FCPF = Forest Carbon Partnership Facility; FIP = Forest Investment Program; GEEREF = Global Energy Efficiency and Renewable Energy Fund (European Union); GEF = Global Environment Facility; IFC = International Finance Corporation; JI = Joint Implementation; LDCF = Least Developed Country Fund (UNFCCC/GEF); PPCR = Pilot Program for Climate Resilience; SCCF = Strategic Climate Change Fund (UNFCCC/GEF); UN-REDD = UN Collaborative Program on Reduced Emissions from Deforestation and Forest Degradation.

CHAPTER 7

Accelerating Innovation and Technology Diffusion

Windmills peppered European landscapes to provide energy for agricultural activities long before the discovery of electricity. Thanks to the forces of innovation and technology diffusion, wind is now powering the first stages of what could become a veritable energy revolution. Between 1996 and 2008 the global installed wind capacity increased twentyfold to stand at more than 120 gigawatts, displacing an estimated 158 million tons of carbon dioxide (CO_2) a year while creating some 400,000 jobs (figure 7.1).[1] Much of this growth is attributable to government incentives and to publicly and privately funded research, driving down the cost of wind technology and driving up efficiency.

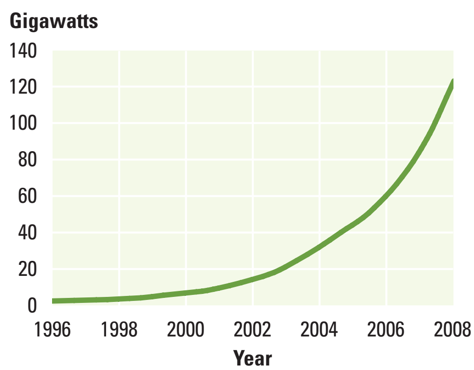
And although most installed capacity is in Europe and the United States, the pattern is shifting. In 2008 India and China each installed more wind capacity than any other country except the United States, and together they host nearly 20 percent of the world's capacity. An Indian company, Suzlon, is one of the world's leading wind turbine manufacturers, employing 13,000 people across Asia. So the global takeoff of wind technology is setting an early precedent for climate-smart development. And complementary advances, such as global geospatial wind resource information, are making siting decisions easier (map 7.1).

Technological innovation and its associated institutional adjustments are key to managing climate change at reasonable cost. Strengthening national innovation and technology capacity can become a powerful catalyst for development.[2] High-income economies, the world's major emitters, can replace their stock of high-carbon technologies with climate-smart alternatives while massively investing in tomorrow's breakthrough innovations. Middle-income

Key messages

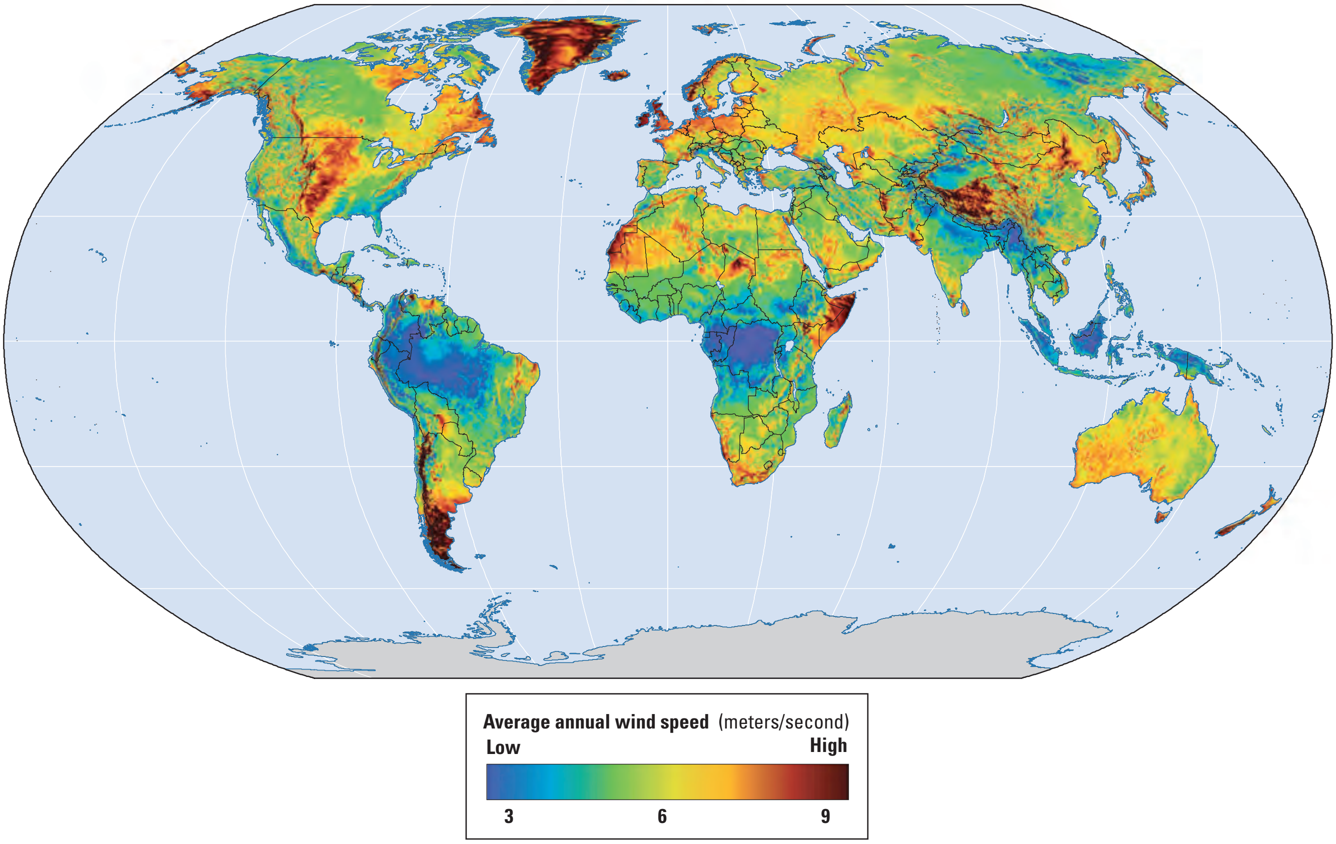
Meeting climate change and development goals requires significantly stepping up international efforts to diffuse existing technologies and develop and deploy new ones. Public and private investment—now in the tens of billions of dollars per year—need to be steeply ramped up to several hundreds of billions of dollars annually. "Technology-push" policies based on increasing public investments in R&D will not be sufficient. They need to be matched with "market-pull" policies that create public and private sector incentives for entrepreneurship, for collaboration, and to find innovative solutions in unlikely places. Diffusing climate-smart technology requires much more than shipping ready-to-use equipment to developing countries: it requires building absorptive capacity and enhancing the ability of the public and private sectors to identify, adopt, adapt, improve, and employ the most appropriate technologies..

Figure 7.1 Global cumulative installed wind capacity has soared in the past decade



Source: Global Wind Energy Council 2009.

Map 7.1 Advances in wind mapping open up new opportunities



Source: 3Tier Inc.

Note: This is a 5-kilometer resolution map of average annual wind speed, with the average measured at a height of 80 meters (the height of some windmills), across the world's landmass.

countries can ensure that their investments take them in the direction of low-carbon growth and that their firms reap the benefits of existing technologies to compete globally. Low-income countries can ensure that they have the technological capacity to adapt to climate change, by identifying, assessing, adopting, and improving existing technologies with local knowledge and know-how. As chapter 8 points out, reaping the benefits of technological changes will require significant changes in human and organizational behavior, as well as a host of innovative supportive policies to reduce human vulnerability and manage natural resources.

Yet today's global efforts to innovate and diffuse climate-smart technologies fall far short of what is required for significant mitigation and adaptationin the coming decades. Investment in research, development, demonstration, and deployment (RDD&D) is lacking, and the financial crisis is reducing private spending on climate-smart technology, delaying its diffusion. Mobilizing technology and fostering innovation on an adequate scale will require that countries not only cooperate and pool their resources but also craft domestic policies that promote a supportive knowledge infrastructure and business environment. And most developing countries, particularly low-income countries, have small market sizes which, taken individually, are unattractive to entrepreneurs wishing to introduce new technologies. But contiguous countries can achieve a critical mass through greater regional economic integration.

International cooperation must be scaled up to supply more financing and to formulate policy instruments that stimulate demand for climate-smart innovation, rather than simply focus on research subsidies. The international harmonization of regulatory incentives (such as carbon pricing) can have a multiplier effect on investment by creating economies of scale and by building momentum in the direction of climate-smart technologies. Innovation prizes and procurement subsidies can build demand and stimulate ingenuity. And where research priorities coincide with high costs, joint RDD&D can push out the technical frontiers. The concept of technology transfer needs to be broadened to include country capacities to absorb existing technologies. In this respect an international climate treaty with a focus on specific technological systems or subsystems presents a unique opportunity. Bundling in cost-sharing and technology transfer provisions could facilitate an accord.

Complementary domestic policies can ensure that technology is effectively selected, adapted, and absorbed. But identifying, evaluating, and integrating foreign technologies impose oft-overlooked learning costs, as do their modification and improvement. So the knowledge infrastructure of universities, research institutes, and firms has to be supported to build this capacity.

This chapter draws on the analysis of systems in which technology has withered or thrived and on the plethora of policies and factors that have acted as barriers or catalysts, suggesting what can be achieved if selected policies are combined and scaled up. It first describes the importance of technology in lowering greenhouse gas emissions, the needed tools to advance adaptation to climate change, and the role of both creating competitive economies. It next assesses the gap between invention, innovation, and widespread diffusion in the marketplace. It then examines how international and domestic policies can bridge that gap.

The right tools, technologies, and institutions can put a climate-smart world well within our reach

To keep global temperatures from rising more than 2°C, global greenhouse gas emissions must come down by 50–80 percent in the coming decades. In the short term they can be drastically reduced by accelerating the deployment of existing mitigation technologies in high-emitting countries.

But to achieve the more ambitious medium-term emission objectives will require breakthrough technologies. Four future key technology areas could be at the core of a solution: energy efficiency; carbon capture and storage; next-generation renewables, including biomass, wind and solar power; and nuclear power (see chapter 4).[3] All four need more research, development, and demonstration (RD&D) to determine whether they can be rapidly deployed in the marketplace without adverse consequences.

Despite their great promise, both short- and medium-term emission reduction strategies face major challenges. End-use technologies that improve efficiency and use sources with low emissions can dampen total energy demand, but they require changing the behavior of individuals and firms (see chapter 8). Carbon capture and storage could play a large role if geologically appropriate sites can be identified near power plants and if governments provide resources and policies to enable long-term sequestration.[4] Biotechnology and second-generation biofuels have great potential for mitigating carbon emissions but with increasing demands on land use (see chapter 3). Wind and solar power (both photovoltaic and solar thermal) could expand faster if energy storage and transmission improve. A new generation of nuclear power plants could be deployed extensively throughout the world but would have to overcome institutional constraints, safety and proliferation issues, and popular resistance in some countries. In addition, some have proposed that geoengineering options could not only decrease emissions rates but also temper the impacts of climate change (box 7.1).

The role of technology and innovation in adaptation has been much less studied than for mitigation, but it is clear that future climate conditions will be fundamentally different from the ones today. Responding to changes outside of historic experience will require increased institutional coordination on a regional scale, new tools for planning, and the ability to respond to multiple

BOX 7.1 *Geoengineering the world out of climate change*

Given the pace of climate change, current proposals for mitigation and adaptation may not be sufficient to avoid considerable impacts. Thus, possible geoengineering options are receiving increasing scrutiny. Geoengineering can be defined as actions or interventions taken for the primary purpose of limiting the causes of climate change or the impacts that result. They include mechanisms that could enhance carbon dioxide (CO_2) absorption or sequestration by the oceans or by vegetation, deflect or reflect incoming sunlight, or store CO_2 produced by energy use in reservoirs. The last of these is discussed in chapter 4, so this box focuses on the other two classes of options.

Possible options for sequestering additional carbon dioxide include terrestrial management practices that increase carbon held in soils or trees, as discussed in chapter 3. It may also be possible to stimulate phytoplankton growth and algal blooms in the oceans by adding needed nutrients such as iron or urea. As these tiny plants photosynthesize, they take up carbon dioxide from surface waters. The effectiveness of such enhanced approaches will depend on what happens to the CO_2 over the longer term; if it is integrated into the waste products from animals that eat the plankton and settles to the seafloor, then the CO_2 will essentially be removed from the system for millennia. However, recent research shows that previous quantifications of carbon removal capacity may have been greatly overestimated. Also, more experiments need to be done on the duration of sequestration as well as the potential toxicological impacts of sudden increases in iron or urea in marine ecosystems. If further studies confirm its potential, this is one geoengineering option that could be started quickly and at relevant scale.

Bringing cool, nutrient-rich water to the ocean's surface could also stimulate increased marine productivity and potentially remove CO_2 from the surface water. Such cooling would also be beneficial for coral, which are very sensitive to higher temperatures. Finally, cooling surface water could also dampen hurricane intensities. Initial research on a wave-powered pump to bring cool water to the surface suggests that the approach might work, but much more research and investigation is needed.

Other geoengineering options to remove greenhouse gases include scrubbing gases from the atmosphere with a CO_2 absorbing solution (and then sequestering the captured carbon below the land surface or in the deep ocean), or using lasers to destroy long-lived halocarbon molecules—best known as culprits in ozone depletion but also powerful greenhouse gases (see focus A on science). These options are still in the early experimental stage.

Several approaches to reflect incoming sunlight have been offered. Some of these could be targeted to particular regions, to prevent further melting of Arctic sea ice or the Greenland ice sheet, for example. One approach would be to inject sulfate aerosols into the atmosphere. This has shown to be an effective method for cooling—the 1991 eruption of Mount Pinatubo resulted in the earth cooling by nearly 1°C for about a year. To maintain this type of cooling, however, a constant stream or regular injections of aerosol must be released. Further, sulfate aerosols can exacerbate ozone depletion, increase acid rain, and cause adverse health impacts.

Alternatively, sea mist could be sprayed into the sky from a fleet of automated ships, thus "whitening" and increasing reflectivity of the low marine clouds that cover a quarter of the world's ocean. However, uneven cloud distribution could lead to regional cold and hot spots and droughts downwind of the spray vessels.

Increasing the reflectivity of the land surface would also help. Making roofs and pavements white or light-colored would help to reduce global warming by both conserving energy and reflecting sunlight back into space and would be the equivalent of taking all the cars in the world off the road for 11 years.

Another proposal would place a solar deflector disk between the Sun and Earth. A disk of approximately 1,400 kilometers in diameter could reduce solar radiation by approximately 1 percent, about equivalent to the radiative forcing of emissions projected for the 21st century. But analysis shows that the most cost-effective approach for implementing this strategy is to set up a manufacturing plant for the deflector on the Moon, hardly a straightforward task. Similar ideas using multiple mirrors (such as 55,000 orbiting solar mirrors each roughly 10 square kilometers in size) have been discussed. However, when each of the orbiting mirrors passed between the Sun and Earth, they would eclipse the Sun, causing sunlight at the earth's surface to flicker.

There are even geoengineering proposals more akin to weather modification, such as attempting to push advancing tropical storms out to sea and away from human settlements to reduce damage. Although research on such ideas is in its very earliest stages, the newest climate models are becoming capable of analyzing the potential effectiveness of such proposals, something that was not possible when hurricane modification was first attempted several decades ago.

Although it may be possible for geoengineering to be undertaken by one nation, every nation would be affected by such actions taken. For this reason, it is essential that discussions begin on governance issues relating to geoengineering. Already, investor-funded experiments in support of iron fertilization have raised questions over what international entity or institution has jurisdiction. Questions about using geoengineering to limit the intensity of tropical cyclones or Arctic warming would add complexity. Thus, in addition to scientific research on possible approaches and their impacts, social, ethical, legal, and economic research should be supported to explore what geoengineering are and are not within bounds of international acceptance.

Sources: S. Connor, "Climate Guru: 'Paint Roofs White.'" *New Zealand Herald*, May 28, 2009; American Meteorological Association, http://www.ametsoc.org/policy/2009geoengineeringclimate_amsstatement.html (accessed July 27, 2009); Atmocean, Inc., http://www.atmocean.com/ (accessed July 27, 2009); MacCracken 2009; "Geo-engineering: Every Silver Lining Has a Cloud," *Economist*, January 29, 2009; see also U.S. Energy Secretary Steven Chu, http://www.youtube.com/watch?v=5wDIkKroOUQ.

environmental pressures occurring concomitantly with climate change. Greater investments are needed in understanding vulnerability, in conducting iterative assessments, and in developing strategies for helping societies cope with a changing climate.[5]

Integrating climate considerations into development strategies will foster thinking about adaptation.[6] Chapter 2 discusses how climate change will require designing appropriate physical infrastructure and protecting human health. Chapter 3 illustrates how it adaptation will require new ways to manage natural resources. Promoting diversification—of energy systems, agricultural crops, and economic activities, for example—can also help communities cope with rapidly changing conditions. Innovation will be a necessary ingredient for all of these activities.

Research is also required to understand the effects of climate change and different adaptation options on individual countries. This research must characterize the effects of multiple stresses on natural and socioeconomic systems, biodiversity vulnerability and preservation, and changes in atmospheric and oceanic circulation. Such research has to produce new monitoring tools, new strategies to enhance resilience, and better contingency planning. Scientific capacity at the national level is thus required.

The capacity to tackle mitigation and adaptation will help build strong competitive economies

Many advanced technologies, such as information and communication technologies, can help specifically with climate change yet are generic enough for use across a wide range of productivity-enhancing areas. Sensors are valuable in industrial automation but can also help waste managers limit pollution. Mobile phones have helped help in responding to impending disaster, as in the coastal village of Nallavadu, India, during the 2004 tsunami,[7] but they can also increase business productivity. In parts of Benin, Senegal, and Zambia mobile phones are used to disseminate information about food prices and innovations in farming techniques.[8]

Harnessing the technological opportunities arising from climate change concerns can also create opportunitiesfor technological leadership and a new competitive edge. China, for example, has not yet locked in to carbon-intensive growth and has enormous (and economically attractive) potential for leapfrogging old inefficient technologies. Unlike in developed countries a large share of China's residential and industrial capital stock of the next decade is yet to be built. By using existing technologies, such as optimizing motor-driven systems (pumps and compressors), China could reduce its industrial energy demand in 2020 by 20 percent while increasing productivity.[9]

The current global recession can provide a platform for innovation and climate-smart growth. Crises can spur innovation because they cause an urgent focus on mobilizing resources and break down barriers that normally stand in the way of innovation.[10] And the opportunity cost of research and development (R&D), a long-term investment, is lower during an economic crisis.[11] In the early 1990s Finland's recovery from a severe economic recession was credited largely to its restructuring into an innovation-based economy, with sharp increases in government spending on R&D paving the way for the private sector. The same could be achieved with climate-smart R&D.

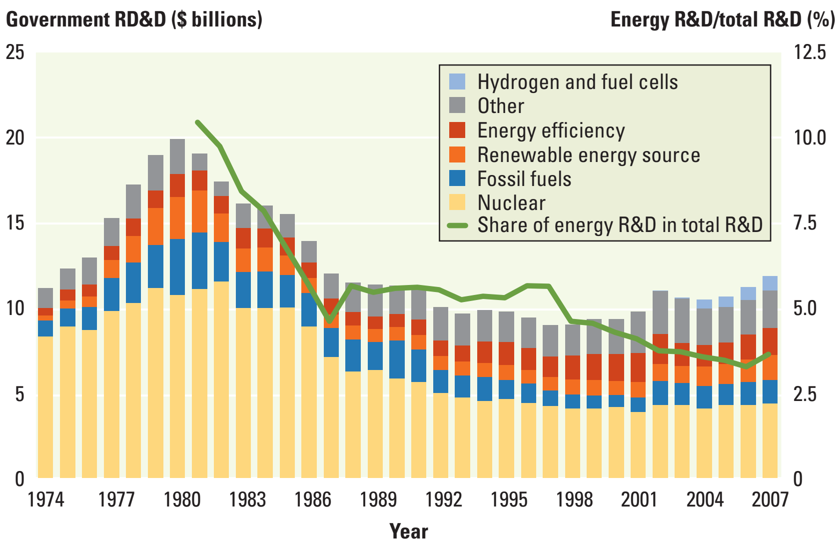
And with high rates of return, R&D presents untapped opportunities for economic growth. Most measures of rates of return on R&D are in the range of 20 to 50 percent, much higher than on investments in capital.[12] Estimates also show that developing countries could invest more than twice as much as they now do.[13] Yet, experience shows that R&D is procyclical, rising and falling with booms and busts, and firms tend to be short-sighted during recessions, limiting their investments in innovation even though this is a suboptimal strategy.[14] The stimulus packages developed by many countries in reaction to the recession offer a timely opportunity for new investments in climate-smart innovation. (see chapter 1).[15]

The current global recession also provides opportunities for economic restructuring in high-income countries that are locked into high-carbon lifestyles.

Overcoming technological inertia and institutional incumbency in these countries remains one of the most critical obstacles to the transition to a low-carbon economy.[16] Inertia and incumbency are themselves attributes of existing technoeconomic systems and cannot be wished away through diplomatic processes. Unseating them will entail actual changes in economic structures. Climate-smart policies will need to include mechanisms to identify those who stand to lose and minimize socioeconomic dislocations.

Although climate-smart innovation is concentrated mostly in high-income countries, developing countries are starting to make important contributions. Developing countries accounted for 23 percent ($26 billion) of the new investments in energy efficiency and renewable energy in 2007, up from 13 percent in 2004.[17] Eighty-two percent of those investments were concentrated in three countries—Brazil, China and India. The world's best-selling developer and manufacturer of on-road electric cars is an Indian venture, the Reva Electric Car Company. As a first-mover it has penetrated the auto manufacturer market, including in high-income countries.[18]

Figure 7.2 Government budgets for energy RD&D are near their lows, and nuclear dominates



Sources: IEA 2008a; IEA, http://www.iea.org/Textbase/stats/rd.asp (accessed April 2, 2009); Organisation for Economic Co-operation and Development (OECD), http://www.oecd.org/statsportal (accessed April 2, 2009).

Note: RD&D calculated at 2007 prices and exchange rates. Values on left axis are for RD&D (that is, including demonstration in addition to research and development), as is typical in the energy sector. However because totals of cross-sectoral R&D alone are available, the right axis only includes R&D.

BRIICS countries (Brazil, the Russian Federation, India, Indonesia, China, and South Africa) accounted for only 6.5 percent of global renewable energy patents in 2005,[19] but they are quickly catching up to high-income countries, with annual patenting growth rates more than twice those of the European Union (EU) or the United States. And they are developing a technological edge in renewable energy technologies, with roughly 0.7 percent of their patents filed in this sector from 2003 to 2005, compared with less than 0.3 percent in the United States. In 2005 China was seventh in overall renewable energy patenting and second only to Japan in geothermal and cement inventions, two major potential sources of emission reduction.[20]

All countries will need to step up their efforts to diffuse existing climate-smart technologies and create new ones

Neither public nor private funding of energy-related research, development, and deployment is remotely close to the amounts needed for transitioning to a climate-smart world. In absolute terms, global government energy RD&D budgets have declined since the early 1980s, falling by almost half from 1980 to 2007 (figure 7.2). Energy's share in government research and development budgets (not including demonstration) also plunged, from 11 percent in 1985 to less than 4 percent in 2007 (green line in figure 7.2), heavily concentrated in nuclear power. Comparisons with public subsidies for energy or petroleum products are even more stark (figure 7.3). But recent calls for increases in energy research and development to $100 billion to $700 billion a year[21] are achievable. Japan is already taking the lead, spending 0.08 percent of its gross domestic product (GDP) on public energy RD&D, far ahead of the 0.03 average in the group of high-income and upper-middle-income-country members of the International Energy Agency.[22]

Given a recent upsurge, private spending on energy RD&D, at $40 billion to $60 billion a year, far exceeds public spending. Even so, at 0.5 percent of revenue, it remains an order of magnitude smaller than the 8 percent of revenue invested in RD&D in the electronics industry and the 15 percent in the pharmaceuticals sector.[23]

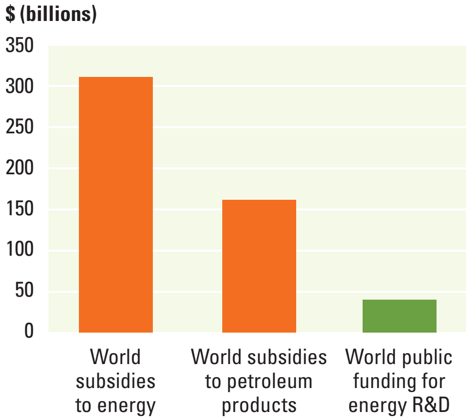
Progress in some technologies has just been too slow. Although patenting in renewable energy has grown rapidly since the mid-1990s, it was less than 0.4 percent of all patents in 2005, with only 700 applications.[24] Most growth in low-carbon technology patenting has been concentrated in the areas of waste, lighting, methane, and wind power, but improvement in many other promising technologies like solar, ocean, and geothermal power has been more limited (figure 7.4), with little of the needed progress toward steep cost reduction.

Developing countries are still lagging in innovation for adaptation. While it is more cost-effective to adopt technologies from abroad than to reinvent them, in some cases technological solutions for local problems do not exist.[25] So innovation is not only relevant to high-income economies. For example, advances in biotechnology offer potential for adapting to climate-related events (droughts, heat waves, pests, and diseases) affecting agriculture and forestry. But patents from developing countries still represents a negligible fraction of global biotechnology patents.[26] That will make it difficult to develop location-specific agricultural and health responses to climate change. Moreover, little spending on agricultural R&D—though on the rise since 1981—occurs in developing countries. High-income economies continue to account for more than 73 percent of investments in global agricultural R&D. In developing countries the public sector makes 93 percent of agricultural R&D investments, compared with 47 percent in high-income countries. But public sector organizations are typically less effective at commercializing research results than the private sector.[27]

International collaboration and cost sharing can leverage domestic efforts to promote innovation

Cooperation to drive technological change covers legislative and regulatory harmonization, knowledge sharing and coordination, cost sharing, and technology transfer

Figure 7.3 Annual spending for energy and climate change R&D pales against subsidies



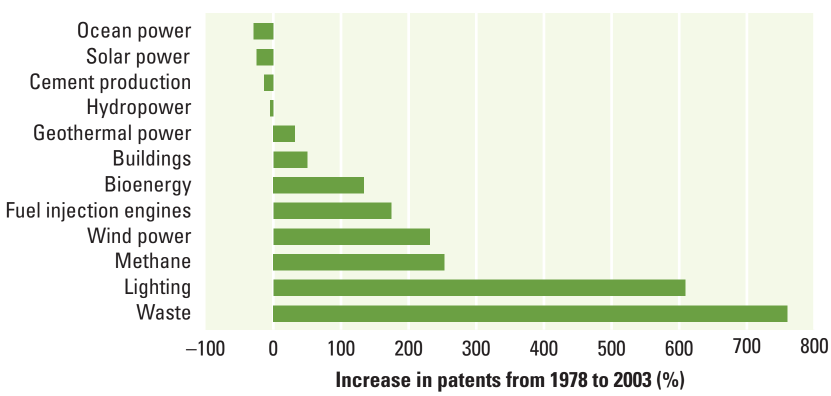
Sources: IEA 2008a; IEA 2008b; IEA, http://www.iea.org/Textbase/stats/rd.asp (accessed April 2, 2009).

Note: Global subsidy estimates are based on subsidies shown for 20 highest-subsidizing non-OECD countries only (energy subsidies in OECD countries are minimal).

(table 7.1). Some efforts are under way, while other opportunities are as yet untapped.

Because of the mix of required technologies and their stages of development and because their global adoption rates are so widely varied, all these approaches to cooperation will be required. Moreover, climate-smart technology cannot be produced through fragmented efforts. Innovation has to be seen as a system of multiple interacting actors and technologies, path dependency, and learning processes, not just as a product of R&D (box 7.2).[28] Subsidies for research, development, demonstration, and deployment have to be combined with market incentives for firms to innovate and

Figure 7.4 The pace of invention is uneven across low-carbon technologies



Source: Dechezlepretre and others 2008.

Table 7.1 International technology-oriented agreements specific to climate change

Type of agreements	Subcategory	Existing agreements	Potential impact	Risk	Implementation	Target
Legislative and regulatory harmonization	Technology deployment and performance mandates	Very little (mainly EU)	High impact	Wrong technological choices made by government	Difficult	Energy technologies with strong lock-in effects (transport) and that are highly decentralized (energy efficiency)
Knowledge sharing and coordination	Knowledge exchange and research coordination	Many (such as International Energy Agency)	Low impact	No major risk	Easy	All sectors
	Voluntary standards and labels	Several (EnergyStar, ISO 14001)	Low impact	Limited adoption of standards and labeling by private sector	Easy	Industrial and consumer products; communication systems
Cost-sharing innovation	Subsidy-based "technology push" instruments	Very few (ITER)	High impact	Uncertainty of research outcomes	Difficult	Precompetitive RD&D with important economies of scale (carbon capture and storage, deep offshore wind)
	Reward-based "market pull" instruments	Very few (Ansari X-prize)	Medium impact	Compensation and required effort may result in inappropriate levels of innovation	Moderate	Specific medium-scale problems; solutions for developing-country markets; solutions not requiring fundamental R&D
	Bridge-the-gap instruments	Very few (Qatar-UK Clean Technology Investment Fund)	High impact	Funding remains unused due to lack of deal flow	Moderate	Technologies at the demonstration and deployment stage
Technology transfer	Technology transfer	Several (Clean Development Mechanism, Global Environment Facility)	High impact	Low absorptive capacities of recipient countries	Moderate	Established (wind, energy efficiency), region-specific (agriculture), and public sector (early-warning, coastal protection) technologies

Sources: Davis and Davis 2004; De Coninck and others 2007; Justus and Philibert 2005; Newell and Wilson 2005; Philibert 2004; World Bank 2008a.

move technologies along the innovation chain (figure 7.5).[29] And innovation has to rely on knowledge flows across sectors and on advances in such broad technologies as information and communications technologies and biotechnology.

Regulatory harmonization across countries forms the backbone of any climate-smart technology agreement

Harmonized incentives with a broad geographic reach can create large investor pools and markets for climate-smart innovation. Carbon pricing, renewable portfolio standards that regulate the share of energy coming from renewable sources, and performance mandates such as automobile fuel economy standards (see chapter 4) are cost-effective and can promote the development and diffusion of low-carbon technologies. For example, a number of countries have initiated measures to phase out incandescent light bulbs, because more efficient technologies such as compact fluorescent lamps as well as light emitting diodes now exist. Harmonized at a global scale, these regulations can drive the market for low-carbon products in the same way that the

BOX 7.2 *Innovation is a messy process and can be promoted only by policies that address multiple parts of a complex system*

In most countries, government policy is still driven by an outdated linear view of innovation, that perceives innovation as happening in four consecutive stages.

- R&D, to find solutions to specific technical problems and apply them to new technologies.
- Demonstration projects, to further adapt the technology and demonstrate its functioning in larger-scale and real-world applications.
- Deployment, once fundamental technical barriers have been resolved and the commercial potential of a technology becomes apparent.
- Diffusion, when technology becomes competitive in the market.

But experience shows that the process of innovation is much more complex. Most innovations fail in one stage or another. Feedback from manufacturers in the deployment stage, or from retailers and consumers in the diffusion stage, trickles back to the earlier stages, completely modifying the course of innovation, leading to new, unexpected ideas and products and sometimes to unforeseen costs. Sometimes breakthrough innovations are driven not by R&D but by new business models that put together existing technologies. And learning curves, whereby unit costs decline as a function of cumulative production or cumulative RDD&D, are not well understood.

So why does this matter for policy? The linear view gives the misleading impression that innovation can be managed simply by supplying more research inputs (technology push) and creating market demand (market pull). While both types of policy are extremely important, they ignore the contributions of the numerous interactions among the actors involved in the different stages of innovation: firms, consumers, governments, universities, and the like. Partnerships, learning by selling or buying a technology, and learning through imitation play critical roles. Equally critical are the forces that drive diffusion. The compatibility, perceived benefits, and learning costs of using a new product are all key factors for innovation. Effective policies must view innovation as part of a system and find ways to stimulate all these facets of the innovation process, particularly where there are market gaps.

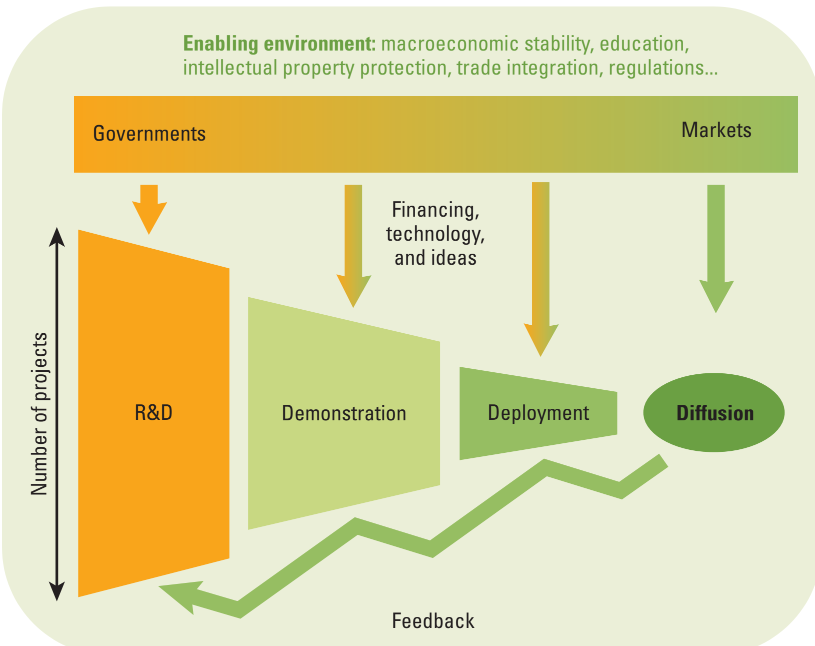
Sources: Tidd 2006; World Bank 2008a.

harmonization of GSM communications standards for mobile phones created a critical mass for the mobile phone market in Europe in the 1990s.

Knowledge-sharing and coordination agreements are useful complements

Knowledge agreements can address market and system failures in innovation and diffusion. Such agreements coordinate national research agendas, information exchange systems, and voluntary standards and labeling schemes. Research coordination agreements include many of the International Energy Agency's 42 technology agreements, where countries finance and implement their individual contributions to different sector-specific projects, ranging from advanced fuel cells to electric vehicles.[30] Such agreements can avoid duplicating investments across countries. They allow countries to jointly decide on who works on what, thus ensuring that no key technologies are ignored, particularly those relevant to developing countries (such as biofuels from developing-country feedstocks and lower-capacity power generation). Information exchange systems include the Global Earth Observation System of Systems, which will make data available from various observation and measurement systems (box 7.3). Prominent examples of international coordination in labels are the Energy Star program agreements, whereby government agencies in various countries

Figure 7.5 Policy affects every link of the innovation chain



Source: Adapted from IEA 2008a.

BOX 7.3 *Innovative monitoring: Creating a global climate service and a "system of systems"*

Demand for sustained and reliable data and information on trends, unusual events, and long-range predictions has never been greater than it is today. A number of public and private entities in sectors as diverse as transportation, insurance, energy, water, agriculture, and fisheries are increasingly incorporating climate information into their planning. Such forecasting has become a critical component of their adaptation strategies.

A global climate services enterprise (GCS) could provide the climate-relevant information that society needs to better plan for and anticipate climate conditions on timescales from months to decades. Such an enterprise would build on existing observation systems but must go far beyond them. A GCS would provide information to help answer questions about appropriate city infrastructure to cope with the 100-year extreme precipitation and storm surge eventsthat will now occur at higher magnitude and greater frequency, help farmers decide on appropriate crops and water management during droughts, monitor changing stocks and flows of carbon in forests and soils, and evaluate efficacy of disaster response strategies under changing climate conditions.

A GCS will require innovative partnerships across governments, the private sector, and other institutions, and its design will be quite critical. Beginning with today's observations and modeling capacity, a connected multi-hub-and-spoke design should be developed whereby global services are provided to regional service providers that in turn deliver information to local providers. This eliminates the requirement that every community develop very sophisticated information on their own.

Building the Components of a GCS

Some of the necessary information to develop a GCS is being provided by United States National Meteorological and Hydrologic Service Centers and increasingly by Global Climate Observing System contributions through various government agencies and nongovernmental institutions. Also, a number of other institutions, such as the World Data Centers and the International Research Institute, regularly provide climate-related data and products including forecasts on monthly to annual timescales.

There are also a few examples of fledgling regional climate services. One such example is the Pacific Climate Information System (PaCIS), which provides a regional framework to integrate ongoing and future climate observations, operational forecasting services, and climate projections. PaCIS facilitates the pooling of resources and expertise, and the identification of regional priorities. One of the highest priorities for this effort is the creation of a Web-based portal that will facilitate access to climate data, products, and services developed by the U.S. National Oceanic and Atmospheric Administration and its partners across the Pacific region.

Another example is the formation of regional climate centers, which the World Meteorological Organization (WMO) has formally sought to define and establish since 1999. The WMO has been sensitive to the idea that the responsibilities of regional centers should not duplicate or replace those of existing agencies but instead support five key areas: operational activities, including the interpretation of output from global prediction centers; coordination efforts that strengthen collaboration on observing, communication, and computing networks; data services involving providing data, archiving it and ensuring its quality; training and capacity building; and research on climate variability, predictability, and impacts in a region.

Integrating climate services with other innovative monitoring systems

Building a comprehensive and integrated system to monitor environmental changes across the planet is beyond the means of any single country, as is analyzing the wealth of data it would generate. That is why the Group on Earth Observation (GEO), a voluntary partnership of governments and international organizations, developed the concept of a Global Earth Observation System of Systems (GEOSS). Providing the institutional mechanisms to ensure the coordination, strengthening, and supplementation of existing global Earth observation systems, GEOSS supports policy makers, resource managers, scientific researchers, and a broad spectrum of decision makers in nine areas: disaster risk mitigation; adaptation to climate change; integrated water resource management; management of marine resources; biodiversity conservation; sustainable agriculture and forestry; public health; distribution of energy resources; and weather monitoring. Information is combined from oceanic buoys, hydrological and meteorological stations, remote-sensing satellites, and internet-based Earth-monitoring portals.

Some early progress:

- In 2007 China and Brazil jointly launched a land-imaging satellite and committed to distribute their Earth observation data to Africa.
- The United States recently made available 40 years of data from the world's most extensive archive of remotely sensed imagery.
- A regional visualization and monitoring system for Mesoamerica, SERVIR, is the largest open-access repository of environmental data, satellite imagery, documents, metadata, and online mapping applications. SERVIR's regional node for Africa in Nairobi is predicting floods in high-risk areas and outbreaks of Rift Valley Fever.
- GEO is beginning to measure forest-related carbon stocks and emissions through integrated models, in situ monitoring, and remote sensing.

Sources: Global Earth Observation System of Systems, http://www.epa.gov/geoss (accessed January 2009); Group on Earth Observations, http://www.earthobservations.org (accessed January 2009); IRI 2006; Note from Tom Karl, National Oceanic and Atmospheric Administration, National Climatic Data Center, 2009; Pacific Region Integrated Climatology Information Products, http://www.pricip.org/ (accessed May 29, 2009); Rogers 2009; Westermeyer 2009.

unify certain voluntary energy-efficiency labeling schemes by providing a single set of energy-efficiency qualifications.[31]

The Montreal Protocol's Technology and Economic Assessment Panels offer a model for a technology agreement on climate change, in this case the effects of ozone depletion. The panels brought together governments, businesses, academic experts, and nongovernmental organizations into work groups to establish the technical feasibility of specific technologies and timetables for phasing out the production and use of chlorofluorocarbons and other ozone-depleting chemicals. The panels showed that technology coordination agreements work best when linked to emission mandates, which provided incentives for industry to participate.[32] One challenge to replicating this model for climate change is that a large number of panels would be required to tackle the wide range of technologies that affect climate change. A more feasible approach would be to initially limit this approach to several strategic sectors.

The European Union's "New Approach" to standardization also offers a model for harmonization of climate-smart standards. Goods traded within the EU must comply with basic safety, public health, consumer protection, and environmental protection rules. The EU first tackled this issue by requiring member states to harmonize legislation containing detailed technical specifications. But this approach caused deadlocks in the European Council and updating legislation to reflect technological progress was difficult. In 1985, the New Approach was designed to overcome this problem. Goods classified under the New Approach must simply comply with very broad, technology-neutral "essential requirements" enshrined in legislation that must be adopted by every EU member state. To meet the New Approach requirements, products can comply with harmonized European standards developed by one of the three regional voluntary standardization bodies. There, technical committees representing a mix of industry, governments, academia, and consumers from different EU countries agree on standards by consensus. Technical committees are open to any stakeholder from any EU member state wishing to participate. A similar approach could harmonize broad climate-smart regulations across countries through a climate treaty supported by voluntary standards developed separately through an open-consensus process.[33]

Voluntary standards, labels, and research coordination are lower-cost means of technology cooperation, but it is difficult to assess whether they generate additional technology investments.[34] It is unlikely that they alone could address the massive investment needs, urgency, and learning-by-doing required for such technologies as carbon capture and storage.

Cost-sharing agreements have the highest potential payoffs, if they can surmount implementation barriers

Cost-sharing agreements can be "technology-push" agreements, where the joint development of promising technologies is subsidized by multiple countries (the top-down, left-most, orange arrow in figure 7.3) before knowing whether they will succeed. Or they can be "market-pull" agreements, where funding, pooled from multiple countries, rewards technologies that have demonstrated commercial potential—providing market signals through feedback loops. They can also bridge the gaps in the innovation chain between research and the market.

Q: figure 7.5, not 7.3?

Research agreements. Only a few international cost-sharing programs support climate-change innovation, among them the $12 billion ITER fusion reactor (box 7.4) and several technology agreements coordinated by the International Energy Agency, with budgets of several million dollars. Another partnership model of research institutions is the Inter-American Institute for Global Change Research, an intergovernmental organization supported by 19 countries in the Americas, with a focus on the exchange of scientific information among scientists and between scientists and policymakers. The mission of the center is to encourage a regional, rather than national, approach.

There is potential for massively scaling up cost-sharing research agreements for

BOX 7.4 *ITER: A protracted start for energy R&D cost sharing*

ITER is an international research and development project to demonstrate the scientific and technical feasibility of nuclear fusion to generate electricity without producing the radioactive waste associated with nuclear fission. The partners in the project are China, the European Union, India, Japan, the Republic of Korea, the Russian Federation, and the United States.

ITER was proposed in 1986, and the design of its facilities was finalized in 1990. The initial schedule anticipated construction of an experimental reactor beginning in 1997, but this was postponed by negotiations over experimental design, cost sharing, the design site, the construction site, and staffing. Several countries pulled out of ITER, some later rejoined, and some temporarily withdrew their funding.

ITER shows the difficulties in negotiating a more than $12 billion research project with uncertain outcomes. Funding for construction was finally approved in 2006. ITER is expected to be operational for 20 years, once construction is completed in around 2017.

Source: http://www.iter.org (accessed December 12, 2008).

Note: ITER originally stood for International Thermonuclear Experimental Reactors but now is simply known as ITER.

fundamental research and demonstration projects, where expenses and uncertainty are high. Research consortia are also well suited to conduct long-term research with economies of scale and economies of learning, such as carbon capture and storage (box 7.5), third-generation photovoltaic, deep offshore wind, second-generation biofuels, and climate-monitoring technologies. The scope for cooperation is narrower for technologies closer to commercialization, when intellectual property rights become more problematic and when individual countries may want a first-mover advantage.

Cost-sharing agreements can focus on a few high-priority areas and be negotiated through centralized international institutions with existing negotiation structures. The ITER project shows that large-scale cost-sharing agreements are difficult to implement when countries can renege on their commitments or disagree on implementation. Ensuring the sustainability of funding for such agreements will require added incentives, such as withdrawal penalties or contractual commitments by each party to increase their funding (up to a cap) when new parties join, in order to discourage free-riding and lock cost-sharing agreements into a climate treaty.[35] Most of the technological efforts can be borne by high-income countries. But to be effective, collaborative research agreements must subsidize the involvement of developing countries, particularly fast-growing middle-income countries that must start early to build technological capacity that will be essential for their long-term climate-smart development. The private sector must also be included in research partnerships to ensure technologies can later be diffused through the market.

Market-pull, reward-based agreements. Many breakthrough innovations come from unlikely places that can be easily missed by grant funding programs. In 1993 Shuji Nakamura, a lone engineer working with a limited budget in a small company in the Japanese countryside, astonished the scientific community with the first successful blue-light-emitting diodes. This was the critical step for creating today's brilliant high-efficiency white-light-emitting diodes.[36] Many of the leading global innovators—including the computer giant Dell—spend much less than their industry peers on R&D as a share of sales.[37] But they are uniquely skilled at scoping the horizon for high-potential technologies and ideas, at collaborating with others on R&D, and at bringing new technologies to the market.[38] Some of the most promising climate-smart technologies are likely to come out of sectors that are typically not associated with climate change. For example, super-water-absorbent polymers could play a key role in promoting revegetation of drylands and other degraded ecosystems by holding water in the soil. But much of the interest in this technology is concentrated among manufacturers of products such as diapers. Similarly, producers of water repellent materials could manufacture clothing that requires less washing, with significant reductions in water and energy use.

Financial instruments that reward risk taking, rather than picking winners from the start, represent a tremendous unexploited opportunity. Solutions to technological problems can come from rapid advances in unexpected places or from new business models that traditional R&D subsidy programs can easily overlook. New

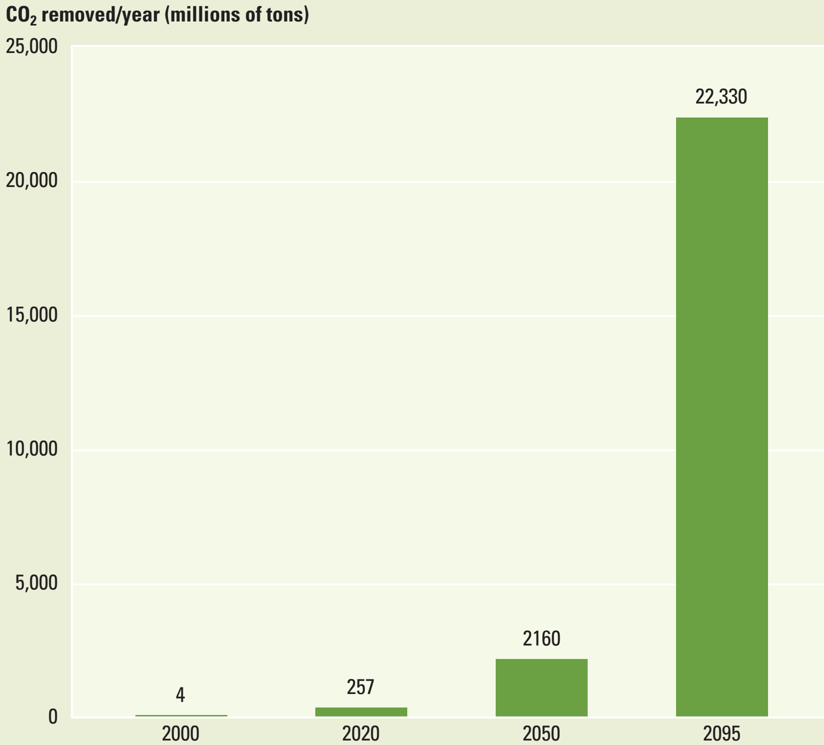
BOX 7.5 *Technologies on the scale of carbon capture and storage require international efforts*

For carbon capture and storage to achieve a fifth of the emission reductions needed to limit atmospheric concentrations to, for example, 550 parts per million, the technology has to ramp up from the 3.7 million tons of carbon sequestered today[a] to more than 255 million tons by 2020 and at least 22 billion tons by the end of the century, or about the same amount of current global emissions from energy use today (figure). Each capture and storage plant costs between $500 million and $2 billion to construct, and deploying the 20–30 needed by 2020 to prove the commercial viability of the technology would be prohibitive for a single country. There are only four commercial end-to-end carbon capture and storage projects, and their storage capacity is one to two orders of magnitude smaller than the capacity a commercial 1,000 megawatt plant would need over its expected operational lifetime.

Source: Edmonds and others 2007; IEA 2006; IEA 2008b.

a. To convert tons of carbon to CO_2, multiply by 3.67.

Carbon capture and storage technology requires massive additional efforts



Note: Observed data for 2000. For all other years, projects based on needs in order to limit greenhouse gas concentrations to 550 ppm.

global financial instruments give markets the flexibility to find innovative solutions.

Inducement prizes and advanced market commitments are two closely related market-pull incentives for rewarding innovations that attain prespecified technological targets in a competition. Inducement prizes involve a known reward; advanced market commitments are financial commitments to subsidize future purchases of a product or service up to predetermined prices and volumes.

Although there are no examples of internationally funded climate-smart prizes, other recent national public and private initiatives have gathered growing interest. The $10 million Ansari X-Prize was established in the mid-1990s to encourage nongovernmental space flight. The competition induced $100 million of private research investments across 26 teams, leveraging 10 times the prize investment, before the winner was announced in 2004.[39] In March 2008 the X-Prize Foundation and a commercial partner announced a new $10 million international competition to design, build, and bring to market high-fuel-mileage vehicles. One hundred and eleven teams from 14 countries have registered in the competition.[40]

Advanced market commitments, which encourage innovation by guaranteeing some minimum market demand ro reduce uncertainty, have promoted climate-smart technologies through the U.S. Environment Protection Agency, in partnership with nonprofit groups and utilities (box 7.6). A more recent international initiative is a pilot program for pneumococcal vaccines designed by the GAVI Alliance and the World Bank.[41] In 2007 donors pledged $1.5 billion in advanced market commitments to the pilot. Vaccines are bought with donor-committed funds and with minor

Q: "U.S. Environmental Protection Agency"? add "al"?

BOX 7.6 *The Super-Efficient Refrigerator: A pioneer advanced market commitment program?*

In 1991, under the Super-Efficient Refrigerator Program, a consortium of utilities agreed to pool more than $30 million to reward a manufacturer that could produce and market a refrigerator free of ozone-depleting chlorofluorocarbons that used 25 percent less energy than required by existing regulations. The winner would receive a fixed reward for each unit sold, up to the cap set by the fund's size. The Whirlpool company exceeded the performance requirements and won the prize and national publicity. However, because of low market acceptance the company could not sell enough refrigerators to claim the entire prize. Nonetheless, the competition likely produced spillovers, with competing manufacturers designing their own lines of efficient refrigerators.

Sources: Davis and Davis 2004; Newell and Wilson 2005.

funding from recipient countries if they meet specified performance objectives. It is still too early to judge probable success.[42]

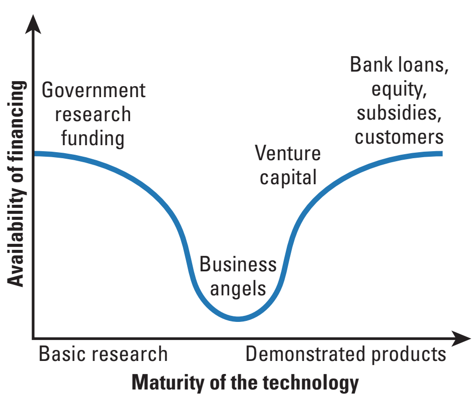
Market-pull inducements can complement but not replace technology-push incentives. Market-pull techniques can multiply public financial resources and foster competition to develop proof-of-concept and working prototypes. They have low barriers to entry—because funding is not awarded on past research credentials, small organizations and organizations from developing countries can compete. But these incentives cannot reduce risk to a point that private investors would be willing to finance large-scale or very early stage research.

Prizes and advanced market commitments offer good potential for multilateral funding. Since prizes do not entail commercialization, they could be offered to solve precommercial research problems in such technologies as battery storage or photovoltaics. Private and public organizations in search of technology solutions could post competitions for designated cash prizes in a global technology marketplace. The World Bank Group is exploring prize competitions for early-stage clean technology innovations supported by the new Earth Fund launched by the Global Environment Facility and the International Finance Corporation.

Advanced market commitments could be useful where deployment learning costs are prohibitive, where there are no lead users willing to pay initial premiums for the technology, or where the market is too small or risky. These include energy generation and use but also adaptation technologies (such as malaria treatments and drought-resistant crop varieties), where the demand side of the market is fragmented (individual governments), financial resources are limited (particularly for developing countries), and the potential size of the market is blurred (by long-term policy uncertainty).[43]

Agreements to bridge the commercialization gap. A major obstacle for innovation is the "valley of death," the lack of financing for bringing applied research to the market (figure 7.6). Governments are typically willing to fund R&D for unproven technologies, and the private sector is willing to finance technologies that have been demonstrated in the marketplace—the R&D block in figure 7.3—but there is little funding for technologies at the demonstration and deployment stages.[44] Governments are often reluctant to fund early-stage ventures for fear of distorting the market, and private investors consider them too risky, with the exception of a limited number of independent investors termed "business angels" and some corporations. Venture capitalists, who typically only fund firms with demonstrated technologies, were able to deploy no more than 73 percent of capital available in the clean technology sector in 2006 because so few firms in this sector had survived the valley of death.[45]

Figure 7.6 The "valley of death" between research and the market



Source: WDR team.

Venture capital funding is also lacking for many types of climate-smart technologies. Investors are unlikely to be attracted to market segments involving particularly high-risk and capital-intensive energy technologies where demonstration costs can be massive. And it is expected that today's financial crisis will slow corporate venture capital, given the higher cost of debt.[46] Moreover, the bulk of the global venture capital industry is in a few developed countries, far from opportunities in several rapidly growing middle-income countries.[47]

Programs to commercialize technology can also support links with potential users of climate-smart technologies, particularly for small firms where breakthrough innovations often occur but which face the greatest financial and market access constraints. To commercialize ideas that meet its technology needs, the U.S. Environmental Protection Agency provides funding to small firms through the Small Business Innovation Research Program.[48] The French government's Passerelle program provides cofunding to large enterprises willing to invest in innovation projects of potential interest in small firms.[49] Other programs provide special grants to collaborative projects to encourage technology spillovers.

Because the gap between research and the market is particularly wide in developing countries and because many solutions to local problems may come from foreign countries, special multilateral funding can support research projects that include developing-country participants. This funding can create incentives for conducting research relevant to developing-country needs such as drought-resistant crops. Multilateral efforts can also promote climate-smart venture capital funds in high-income countries and in the several rapidly growing middle-income countries that have the critical mass of innovative activity and financial infrastructure to attract venture capital investors. This latter group includes China and India. In Israel, the Republic of Korea, and Taiwan, China, the government provided venture capital, acting as a core investor and attracting other funds.[50] Such strategies can provide the "valley of life" needed to nurture nascent technologies to levels where they can take root in the global economy.

The scale and scope of international efforts are far short of the challenge

Technology transfer comprises the broad processes to support flows of information, know-how, experience, and equipment to governments, enterprises, nonprofits, and research and educational institutions. The absorption of foreign technologies depends on much more than financing physical equipment and technology licenses. It requires building national capacity to identify, understand, use, and replicate useful technology. As discussed below, international policies can work hand in hand with national efforts to improve national institutions and create an enabling environment for technology transfer.

International organizations. Many international organizations dealing with environmental challenges are mainly mission focused; these include the World Health Organization, the Food and Agriculture Organization, and the UN Environment Programme. But these entities can be encouraged to collectively enhance the adequacy and coherence of the existing institutions for addressing climate change.

Similarly, many international agreements exist to address particular environmental problems but as these are operationalized, they should be mutually reinforcing.[51] These can be evaluated in terms of goals and means to achieve them in relation to their ability to support mitigation and adaptation of the magnitude expected under a 2°C world or a 5°C or beyond world.

Financing mechanisms. The Clean Development Mechanism (CDM), the main channel for financing investments in low-carbon technologies in developing countries, has leveraged public and private capital to finance over 4,000 low-carbon projects. But the majority of its projects do not involve either knowledge or equipment transfer from abroad.[52] (Chapter 6 discusses the limits of scaling up the CDM to accelerate technology transfers.)

The Global Environment Facility (GEF) is today the largest funder of projects that promote environmental protection while supporting national sustainable development goals. The GEF functions as the financial arm of the UNFCCC and provides support for technology needs assessments for more than 130 countries. Most GEF mitigation funding between 1998 to 2006—about $250 million a year—was directed at removing barriers to the diffusion of energy-efficient technologies.[53] The GEF's adaptation efforts focus on building capacity to identify the urgent and immediate needs of least developed countries. But its impact is limited by its modest proposed adaptation budget of $500 million for the 2010–14 period.[54]

The new Carbon Partnership Facility will provide complementary assistance to developing countries by supporting large and risky investments in clean energy and infrastructure with good potential for long-term emission reductions.[55] The Clean Technology Fund, a $5.2 billion multidonor initiative established in 2008, is another effort to provide low-interest financing for demonstration, deployment, and transfer of low-carbon technologies. In 2009 the Arab Republic of Egypt, Mexico, and Turkey are to be the first countries to benefit from a combined $1 billion of financing from this fund.

The Montreal Protocol shows how sustained multilateral funding can be achieved by making the financing of incremental costs of upgrading technology an obligation of an environmental treaty. The Multilateral Fund for Implementation of the Montreal Protocol provided developing countries with incentives to join the protocol by committing funds for incremental compliance costs.[56] In exchange, developing countries agreed to gradually phase out ozone-depleting substances. The fund provided grants or loans to cover the costs of facilities conversion, training, personnel, and licensing technologies. While the protocol is considered a successful model of technology diffusion, the sources of emissions of greenhouse gases are orders of magnitude larger than chlorofluorocarbons, and many greenhouse gas reduction technologies are not commercially available. A climate change fund similar to the Multilateral Fund would need to be scaled up appropriately.[57]

Financial and technological resources. As chapter 6 emphasizes, substantially more financing for developing countries is necessary. Estimates for additional required investments for mitigation and adaptation ranging from $170 billion to $765 billion annually by 2030. But financial transfers alone will not be enough. Acquiring technology, far from easy, is a long, costly, and risky process ridden with market failures. Adaptation technologies depend on local technical skills and indigenous knowledge because they involve designing systems tailored to local needs (box 7.7).

Even when technology can be imported, it involves a search process, prior technical knowledge, and the skills and resources necessary to use the technology efficiently. That capacity rests on various forms of knowledge, many of which are tacit and cannot be easily codified or transferred. Large-scale energy projects that can be contracted out to foreign firms, for example, require local capacity for policy makers to evaluate their merits, and for operation and maintenance. The European Union is developing legislation for managing risks associated with carbon capture and storage,[58] but few countries have the technical capacity to design such legislation, another barrier to deploying the technology.

BOX 7.7 *A promising innovation for coastal adaptation*

Bangladesh's coastal regions expect more frequent storm surges and tidal floods as a result of climate change. The University of Alabama at Birmingham is working with Bangladeshi researchers on home foundations and frames built of a lightweight composite material that bends—but does not break—in a hurricane and that can float on the rising tide of a coastal surge. Fibers from jute, one of Bangladesh's common plants, are woven with recycled plastics to form an ultrastrong building material. Jute does not require fertilizer, pesticides, or irrigation; is biodegradable; is inexpensive; and is already widely used to produce cloth, ropes, and other items in Bangladesh. Local architects are helping to incorporate the technology in local house designs. Bangladeshi researchers will contribute their expertise on the mass-manufacturing of jute products.

Sources: University of Alabama at Birmingham, http://main.uab.edu/Sites/MediaRelations/articles/55613/ (accessed February 17, 2009); interview with Professor Nassim Uddin, University of Alabama at Birmingham, on March 4, 2009.

Multilateral funding can have a greater impact on technology transfer and absorption by extending its scope from transferring physical and codified technology to enhancing human and organizational absorptive capacities in developing countries. Technology absorption is about learning: learning by investing in foreign technologies, learning through training and education, learning by interacting and collaborating with others outside and inside one's country, and learning through R&D. Multilateral funding can support technology transfer in three ways: by subsidizing investments in homegrown or foreign technologies in developing countries; by subsidizing the involvement of developing countries in the types of knowledge exchange, coordination, and cost-sharing agreements as discussed above; and by supporting national knowledge infrastructures and private sectors, as discussed in the following section.

Public programs, policies, and institutions power innovation and accelerate its diffusion

Innovation is the outcome of a complex system that relies on the individual capacity of a multitude of actors, ranging from governments, universities, and research institutes to businesses, consumers, and nonprofits. Strengthening the capacity of this diverse set of actors, and how these actors interact, is a difficult but necessary task for tackling both development and climate change. Table 7.2 describes key policy priorities for encouraging innovation in countries of different income levels.

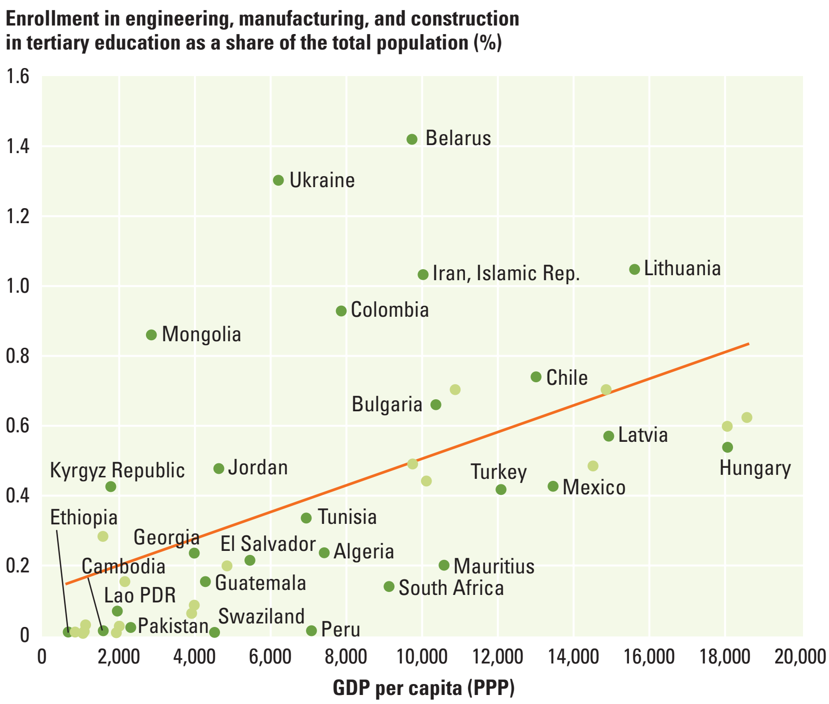
Table 7.2 Key national policy priorities for innovation

Countries	Main policies
Low-income	Invest in engineering, design, and management skills
	Increase funding to research institutions for adaptation research, development, demonstration, and diffusion
	Increase links between academic and research institutions, the private sector, and public planning agencies
	Introduce subsidies for adopting adaptation technologies
	Improve the business environment
	Import outside knowledge and technology whenever possible
Middle-income	Introduce climate-smart standards
	Create incentives for imports of mitigation technologies and, in rapidly industrializing countries, create long-term conditions for local production
	Create incentives for climate-smart venture capital in rapidly industrializing countries with a critical density of innovation (such as China and India)
	Improve the business environment
	Strengthen the intellectual property rights regime
	Facilitate climate-smart foreign direct investment
	Increase links between academic and research institutions, the private sector, and public planning agencies
High-income	Introduce climate-smart performance standards and carbon pricing
	Increase mitigation and adaptation innovation and diffusion through subsidies, prizes, venture capital incentives, and policies to encourage collaboration among firms and other sources and users of climate-smart innovation
	Assist developing countries in enhancing their technological absorptive and innovative capacities
	Support transfers of know-how and technologies to developing countries
	Support middle-income-country participation in long-term energy RDD&D projects
	Share climate change–related data with developing countries
All countries	Remove barriers to trade in climate-smart technologies
	Remove subsidies to high-carbon technologies
	Redefine knowledge-based institutions, especially universities, as loci of the diffusion of low-carbon practices

Source: WDR team.

Skills and knowledge constitute a key pillar for building a climate-smart economy. Basic education provides the foundation of any technology absorption process and reduces economic inequity, but a large enough pool of qualified engineers and researchers is also crucial. Engineers, in particularly short supply in low-income countries, play a role in implementing context-specific technologies for adaptation and are critical to rebuilding efforts after natural disasters (figure 7.7). Bangladesh, particularly prone to hurricanes and sea-level rise, is an extreme example: university students enrolled in engineering represented barely 0.04 percent of the population in 2006, compared with 0.43 percent in the Kyrgyz Republic, a country with a very similar per capita GDP.[59] Equally important are the management and entrepreneurial skills that channel technical knowledge into practical applications in the private sector. And in the public sector skills are required in a wide range of areas including utility regulation, communication, urban planning, and climate policy development.

Figure 7.7 Enrollment in engineering remains low in many developing countries



Source: WDR team based on UNESCO Institute for Statistics, http://stats.uis.unesco.org/unesco/ReportFolders/ReportFolders.aspx (accessed August 30, 2009).

Skills and knowledge can be acquired by investing in the institutions and programs that make up a country's knowledge infrastructure. Institutions such as universities, schools, training institutes, R&D institutions, and laboratories, and such technological services as agricultural extension and business incubation[60] can support the private and public capacity to use climate-smart technologies and make decisions on the basis of sound science.

Another pillar for building a climate-smart economy is to create incentives for the private sector to invest in climate-smart technologies. This means creating not only regulatory incentives but also an enabling environment paired with public support programs for business innovation and technology absorption.

Knowledge infrastructure is a key to creating and adapting local mitigation and adaptation systems

Research institutes in developing countries can help governments better prepare for the consequences of climate change. In Indonesia and Thailand, for example, they are using NASA satellites to monitor environmental characteristics affecting malaria transmission in Southeast Asia, such as rainfall patterns and vegetation status.[61] Research institutes can partner with government agencies and private contractors to identify and design appropriate coastal adaptation technologies and to implement, operate, and maintain them. They can help devise adaptation strategies for farmers by combining local knowledge with scientific testing of alternative agroforestry systems or support forestry management by combining indigenous peoples' knowledge of forest conservation with genetically superior planting material.[62] And they can help firms improve the energy efficiency of their processes through consultancy, testing, troubleshooting, and training.

In middle-income countries research institutions can also solve longer-term mitigation challenges. Mastering the energy technologies that will be useful involves a learning process that can take decades. Agriculture and health depend on biotechnology to develop new technologies and climate science for planning purposes. Development of smart grids for national electricity distribution relies on mastering integrated communications, sensing, and measurement technologies.

Yet after investing in research and academic institutions, many governments have found the contributions to development minimal.[63] The reasons: the research typically is not demand-driven, and there are few links between research institutes, universities, the private sector, and the communities in which they operate (box 7.8).[64] In addition universities in many developing countries have historically focused on teaching and do little research.

Shifting the balance of government funding in favor of competitive research funding, instead of guaranteed institutional funding, can go a long way to increase the effectiveness of public research institutions. In Ecuador the government's Program for Modernization of Agricultural Services finances a competitive research grant program that supports strategic work on innovations to open new export markets by controlling fruit flies, reducing production costs for new export products, and controlling disease and pests in traditional exports crops. The program introduced a new research culture and brought new organizations into the research system. Cofinancing requirements helped increase national research funding by 92 percent.[65] Institutional reforms that give the private sector a greater voice in the governance of research institutions and that reward transfer of knowledge and technology to external clients can also help.[66] In some cases "bridging institutions" such as business incubators can facilitate knowledge spillovers from research institutions. In 2007, 283 clean technology companies were under incubation worldwide (even before including China), twice as many as in 2005.[67]

High-income countries can support the global development and diffusion of climate-smart systems by helping build capacity and partnering with research institutions in developing countries. An example is the International Research Institute for Climate and Society at Columbia University in the United States, which collaborates with local institutions in Africa, Asia, and Latin America.

Another example is the Consultative Group on International Agricultural Research (CGIAR). A donor-funded, decentralized, and cooperative global structure of research institutions, the CGIAR already targets a number of topics relevant to climate adaptation (box 7.9). A similar approach can be used for other climate technologies. Lessons from CGIAR suggest that regional research centers can be funded in developing countries to focus on a limited number

BOX 7.8 *Universities need to be innovative: The case of Africa*

Most donor assistance to Africa does not address the need to harness the world's existing fund of knowledge for long-term development. Higher education enrollments in Africa average close to 5 percent, compared with typical figures of more than 50 percent in developed economies. The challenge, however, is not only to increase access to African universities but also to make them function as engines of development.

There are opportunities for universities to forge closer links with the private sector, train more graduates for professional careers, and diffuse knowledge into the economy. As a model, the United States has a long tradition of land grant colleges, which since the 19th century have been working directly with their communities to diffuse agricultural knowledge. The task ahead requires qualitative change in the goals, functions, and structure of the university. As part of this process, fundamental reforms will be needed in curriculum design, teaching, location, student selection, and university management.

Training will have to become more interdisciplinary to address the interconnected problems that transcend traditional disciplinary boundaries. South Africa's Stellenbosch University offers a shining example of how to adjust curricula to the needs of R&D organizations. It was the first university in the world to design and launch an advanced microsatellite as part of its training. The aim for the program was to build competence in new technologies in the fields of remote sensing, spacecraft control, and earth sciences. Uganda's Makerere University has new teaching approaches that allow students to solve public health problems in their communities as part of their training. Similar approaches can be adopted by students in other technical fields, such as infrastructure development and maintenance.

Sources: Juma 2008; Land grant colleges, https://www.aplu.org/NetCommunity/Page.aspx?pid=183; sea grant colleges, http://www.seagrant.noaa.gov/ (Accessed August 31, 2009).

BOX 7.9 *CGIAR: A model for climate change?*

The Consultative Group on International Agricultural Research (CGIAR) is a strategic partnership of 64 members from developing and industrial countries, foundations, and international organizations including the World Bank. Founded in 1971 in response to widespread concern that many developing countries were in danger of succumbing to famine, it has contributed significantly to agricultural productivity gains through improved crop varieties and played a pivotal role in bringing about the Green Revolution. Over time the CGIAR's mandate has expanded to include policy and institutional matters, conservation of biodiversity, and management of natural resources including fisheries, forests, soil, and water.

The CGIAR supports agricultural research by assisting 15 research centers—independent institutions with their own staff and governance structures, mostly in developing countries—and by running challenge programs. These are independently governed broad-based research partnerships designed to confront global or regional issues of vital importance, such as genetic resource conservation and improvement, water scarcity, micronutrient deficiency, and climate change. In 2008 the CGIAR implemented an independent review of its governance, scientific work, and partnerships. The review concluded that CGIAR research has produced high overall returns since its inception, with benefits far exceeding costs. The benefit of yield-enhancing and yield-stabilizing crop varieties produced by the centers and their national partners is estimated at more than $10 billion annually, attributable largely to improved staple crops such as wheat, rice, and maize. Natural resource management research also shows substantial benefits and high returns on investment. However, the impact of these efforts has varied geographically because of a complex of factors such as local collective action, extension services, or assignment of property rights. The review deemed the CGIAR "one of the world's most innovative development partnerships," thanks to its multidisciplinary research activities and range of collaborations. But it also found that the CGIAR has lost focus on its comparative advantages and that its growing mandate has diluted its impact. At the same time volatile food prices, more extreme weather patterns, growing global demand for food, and increasingly stressed natural resources are challenging the CGIAR like never before.

In December 2008 the CGIAR adopted a new business model. The reform entails a programmatic approach that will focus on a limited number of strategic "mega-programs" on key issues. The reforms also emphasize results-oriented research agenda setting and management, clear accountabilities, streamlined governance and programs, and stronger partnerships. The changes are expected to strengthen the CGIAR so that it can more effectively address many complex global issues, including climate change, but it is still too early to gauge their success.

Sources: Consultative Group on International Agricultural Research. http://www.cgiar.org/ (accessed March 5, 2009); CGIAR Independent Review Panel 2008; CGIAR Science Council 2008; World Bank 2008a.

of well-defined, region-specific topics, such as biomass, bioenergy, energy-efficient buildings, methane mitigation, and forest management.

Knowledge institutions can help inform and coordinate policy, particularly context-specific adaptation policies. As adaptations to climate change begin to be considered within policy processes, it becomes important to share solutions and experiences.[68] When planners, managers, and policy makers begin to recognize how their individual decisions can combine to reduce vulnerability to climate change, there is a tremendous opportunity to enhance coordination among sectors to improve the use of resources and to share this valuable information with other nations, regions, and localities.[69] Establishing and managing a "clearinghouse" that processes and makes available adaptation success stories and options from around the world will help communities faced with adaptation decisions.[70]

Carbon pricing and regulations to mobilize the private sector

As chapter 4 discusses, carbon pricing is essential for catalyzing market-driven innovation and adoption of mitigation technologies.[71] As relative prices change firms are likely to respond with new types of technological investments to economize on the factor that has become more expensive.[72] There is strong evidence that pricing can induce technological change.[73] One study found that if energy prices had remained at their low 1973 level until 1993, the energy efficiency of air conditioners would have been 16 percent lower in the United States.[74]

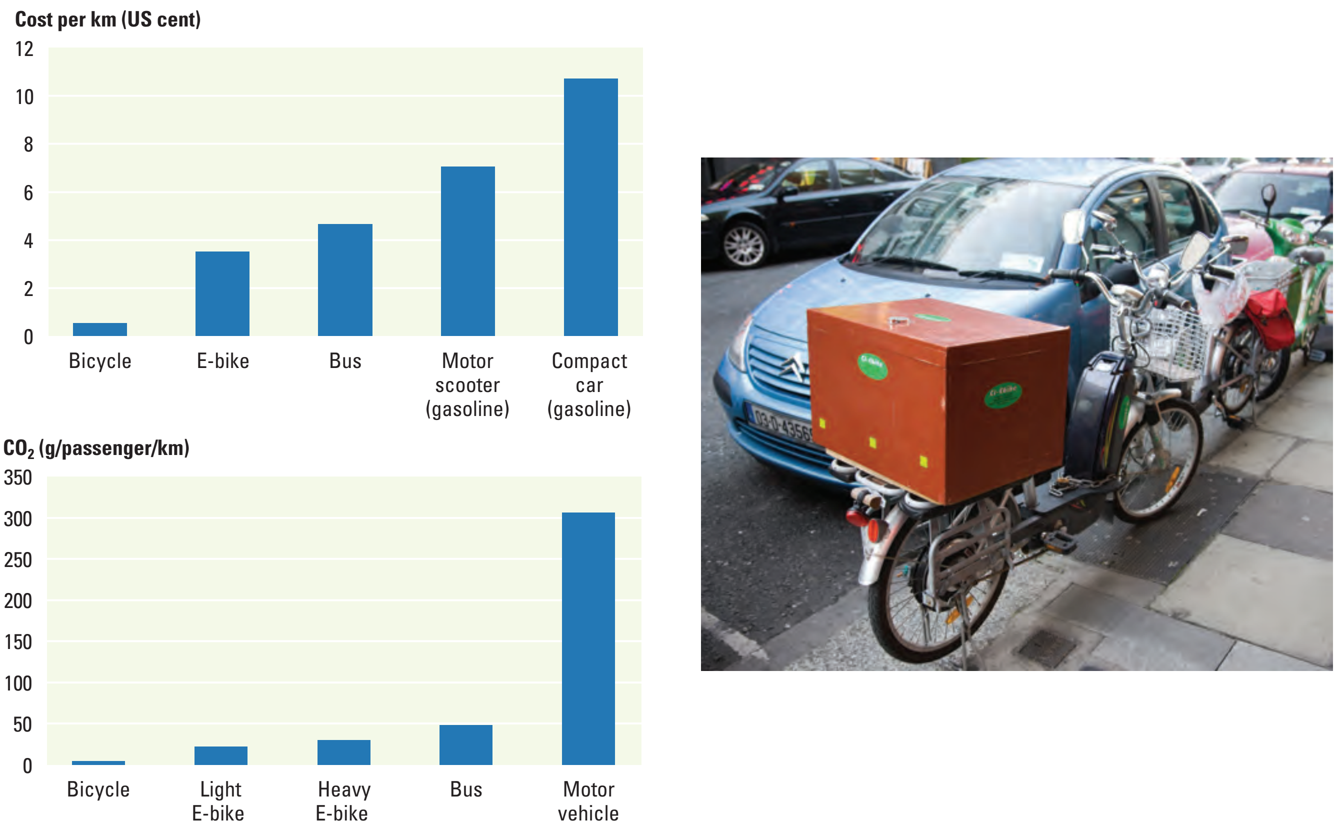
Regulation and its proper enforcement can also induce innovation. Performance standards for emissions or energy efficiency can induce technological change in much the same way as carbon pricing, because they can be associated with implicit prices that firms face in emitting pollutants.[75] In the United States patenting activity in sulfur dioxide (SO_2) emissions technology started to increase only in the late 1960s in anticipation of new national standards on SO_2 control. From 1975 to 1995 technological improvements reduced the capital costs for removing SO_2 from power plant emissions by half, and the share of SO_2 removed rose from less than 75 percent to above 95 percent.[76] Regulations can also provide firms with niche markets to develop new technologies and allow countries to gain a competitive edge. A ban on gasoline-propelled motorbikes in several urban areas of China in 2004—which coincided with technological improvements in electric motor and battery technologies, faster urbanization, higher gasoline prices, and increases in purchasing power—boosted the electric bicycle market from a mere 40,000 in 1998 to 21 million in 2008. E-bikes are now cheaper and cleaner than other motorized modes of transportation, including buses (figure 7.8), and China is exporting these low-carbon vehicles to developed countries.[77]

But regulation alone can have its drawbacks. Unlike price signals, regulations can limit the flexibility of firms, especially when they are technology-specific. They can also result in mitigation options that are more costly for society. But they are a necessary complement to carbon pricing (see chapter 4). Studies have analyzed the comparative effects of environmental regulations and market-based incentives on innovation: the general view is that combining different policy instruments may be the most effective, so long as their development and enforcement are predictable to stakeholders.[78]

An enabling business environment provides the basic framework for climate-smart technology diffusion and innovation

Markets need to function properly to ensure that firms do not face unnecessary risk, have access to information, operate within a well-defined legal framework, and have supportive

Figure 7.8 E-bikes are now among the cheapest and cleanest travel mode options in China



Sources: Cherry 2007; Weinert, Ma, and Cherry 2007; photographs from author.
Note: E-bike emissions refer to full life-cycle, which in this case includes production, energy production, and use. For the regular bicycle only emissions from production are included.

market institutions. Securing land tenure, documenting land rights, strengthening land rental and sale markets, and broadening access to financial services can create incentives for technology transfer for rural smallholders (see chapter 3).[79] But an enabling business environment needs to recognize the basic rights of vulnerable groups, particularly indigenous peoples, heavily dependent on land and natural resources. Many of them have become landless, live on small parcels of land, or do not have secure tenure.[80]

Reducing entry barriers for firms and offering a flexible labor market supports technology start-ups that can create breakthrough innovations and agribusinesses that can bring new types of fertilizers or seeds to farmers.[81] The case of hybrid pearl millet in India shows that market liberalization in the late 1980s increased not only the role of private companies in seed development and distribution but also the rates of innovation.[82] Macroeconomic stability is another pillar of the enabling environment, along with a well-functioning financial sector. Basic infrastructure services, such as continuous energy and water supplies, are also indispensable.

Eliminating tariff and nontariff barriers on clean energy technologies—such as cleaner coal, wind power, solar photovoltaics, and energy-efficient lighting—could increase their traded volume by 14 percent in the 18 developing countries that emit high levels of greenhouse gases.[83] Trade barriers on imports, such as quotas, rules of origin, or unclear customs code specifications, can impede the transfer of climate-smart technologies by raising their domestic prices and making them cost-ineffective. In Egypt the average tariffs on photovoltaic panels are 32 percent, 10 times the 3 percent tariff imposed in high-income members of the Organisation for Economic Co-operation and Development (OECD). In Nigeria potential users of photovoltaic panels face nontariff barriers of 70 percent in addition to a 20 percent tariff.[84] Biofuels are hit particularly hard by tariffs. Tariffs on ethanol and on some biodiesel feedstocks, including import and export duties on Brazilian ethanol, totaled $6 billion in 2006. OECD country subsidies to their domestic biofuels producers came to $11 billion in 2006. As a result, investments are not being made where technology is the most cost-effective. Brazil, the world's lowest-cost ethanol producer, saw a modest 6 percent increase in its ethanol production between 2004 and 2005, whereas the United States and Germany saw production increases of 20 and 60 percent respectively, protected by tariffs of over 25 percent in the United States and over 50 percent in the EU.[85] Removing these tariffs and subsidies would likely reallocate production to the most efficient biofuel producers.[86]

An attractive investment climate for foreign direct investment (FDI) is critical to accelerating technology transfer and absorption.[87] In 2007 FDI accounted for 12.6 percent of total gross fixed capital formation in electricity, gas, and water in developing countries, three times the amount of multilateral and bilateral aid.[88] Transnational corporations based in high-income countries have invested massively in photovoltaic production in India (BP Solar), ethanol in Brazil (Archer Daniels Midland and Cargill), and wind power in China (Gamesa and Vestas). China had one foreign-owned R&D laboratory in 1993 and 700 in 2005.[89] General Electric, a world leader in energy generation and efficiency products, opened global R&D centers in India and China in 2000, centers that now employ thousands of researchers. Figure 7.9 highlights the opportunities brought about by the globalization of wind power equipment R&D and production in middle-income countries.

Developing local production capacity can help these countries ensure their long-term uptake of climate-smart technologies and compete in global markets, driving prices down and performance up. This will occur fastest through licensing or FDI.

To facilitate the transfer of climate-smart technologies, middle-income countries can allow foreign firms to establish fully owned subsidiaries instead of mandating joint ventures or licensing. They can also build a base of local suppliers and potential partners for foreign-invested firms by investing in training and capacity building.[90] And they can ensure that their intellectual property rights adequately protect foreign technology transfer and R&D.

When enforcement of intellectual property rights (IPR) is perceived to be weak (see figure 7.9), foreign firms may not be willing to license their most sophisticated technologies, for fear that competitors will use it—which is the situation for wind equipment in China.[91] Weak IPR enforcement also discourages foreign subsidiaries from increasing the scale of their R&D activities and foreign venture capitalists from investing in promising domestic enterprises.[92] Despite their investments in local manufacturing and R&D, foreign subsidiaries of global wind equipment producers register very few patents in Brazil, China, India, or Turkey. All these countries have weak IPR regimes that could discourage scaling up R&D.[93]

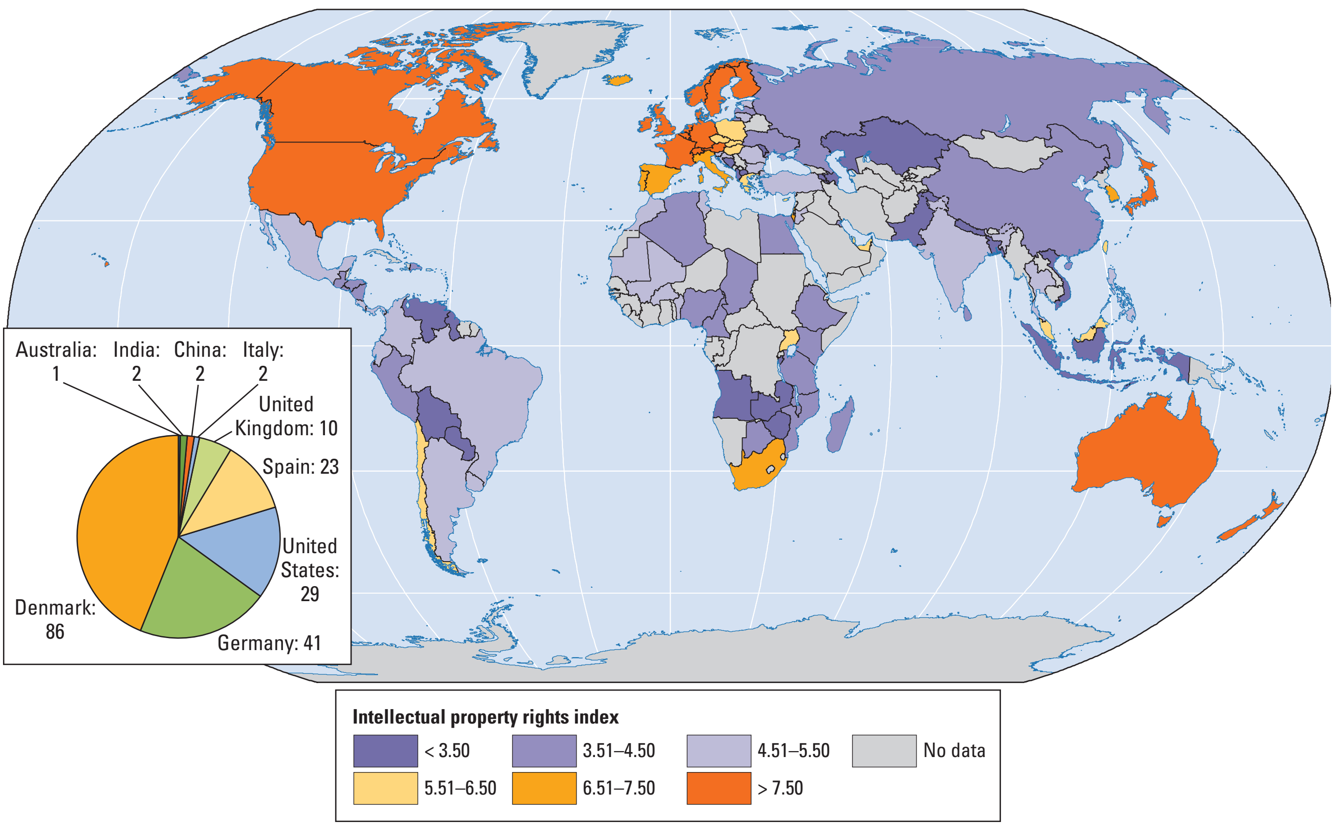
Yet IPRs may also hamper innovation if a patent blocks other useful inventions because it is too broad in scope. Some patent claims on synthetic biology products and processes with promise for synthetic biofuels are perceived by critics to be so broad that scientists fear they may halt scientific progress in related fields.[94] Strong IPRs can also hamper technology transfer if firms refuse to license their technology to keep their market power.

There is no evidence that overly restrictive IPRs have been a big barrier to transferring renewable energy production capacity to middle-income countries, but there are fears that they could one day become so. Brazil, China, and India have joined the ranks of global industry leaders in photovoltaics, wind, and biofuels, often by acquiring licensed technologies. IPR issues may become more of a barrier to technology transfer as patenting activity accelerates in photovoltaics and biofuels and as equipment supplier consolidation continues in the wind sector.[95]

In low-income countries weak IPRs do not appear to be a barrier to deploying sophisticated climate-smart technologies. But predictable and clearly defined IPRs can still stimulate technology transfer from abroad. In these countries, licensing

Q: Please check pie chart in figure 7.9 (rendered at PG, not part of map file)

Figure 7.9 Middle-income countries are attracting investments from the top five wind equipment producers, but weak intellectual property rights regimes constrain technology transfers and R&D capacity



Sources: Published patent data from U.S., Japanese, European, and international patent application databases, annual reports, and Web sites of Vestas, General Electric, Gamesa, Enercon, and Suzlon (accessed on March 4, 2009); Dedigama 2009.

Note: A country's IPR score reflects its ranking according to an IPR index based on the strength of its intellectual property protection policies and their enforcement.

and building local versions of a technology is not a realistic option given the limited domestic production capacity.[96] The absorption of energy technologies generally occurs through imports of equipment. For climate adaptation, patents and plant variety rights held in developed countries are seldom a problem in small and lower-income countries. A patent registered in a specific country can only be protected in that market, and foreign companies do not register their intellectual property in many low-income countries, because they do not represent attractive markets or potential competitors. Poorer countries can thus decide to use a gene or tool from abroad.[97]

High-income countries can ensure that excessive industry consolidation in climate-smart sectors does not reduce incentives to license technology to developing countries. They can also ensure that national policies do not prevent foreign firms from licensing publicly funded research for climate-smart technologies of global importance. In many countries, universities are not allowed to license technology funded by their national government to foreign firms.[98] Other proposals include patent buyouts and the transfer of climate-smart IPRs to the public domain by international organizations.

Developed countries can also ensure that concerns over IPRs and transfer and innovation of climate-smart technologies are considered in international treaties such as those of the World Trade Organization (WTO). The WTO's agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) establishes the minimum legal standards of protection for WTO members. But the TRIPS agreement also recognizes that patents should not be abused, namely, that they should not prevent technology from serving the urgent needs of developing countries. In fact, the TRIPS agreement includes provisions to allow developing countries to exploit patented inventions without the consent of the IPR owner.[99] The WTO and its members can limit abuses in IPR protection if they ensure that the TRIPS agreement grants such exceptions for mitigation and adaptation technologies.

On the whole however, the impact of IPRs on technology transfer may be overstated in comparison with other costs such as management and training and barriers such as limited absorptive capacity. Building engineering competence could go a long way in enhancing the absorptive capacity of developing countries.

Public funding can help firms overcome market failures associated with innovation and technology diffusion

There is a limit to how much carbon prices and emission standards can increase investments in low-carbon technology and innovation. New technologies are not always rapidly adopted even when they become economically attractive to potential users (see box 4.5 in chapter 4). Accelerating technological change requires supplementing carbon pricing and regulations with public funding to explore a wide portfolio of technological options.[100] Well-known market failures leading to private underinvestment in innovation and diffusion have provided the basis for public funding policies for decades.[101]

In middle-income countries with industrial capacity, financial support can go to the local design, production, and export of climate-smart systems. Public funding policies can broadly define innovation to include adapting, improving, and developing products, processes, and services that are new to a firm, irrespective of whether they are new to their markets. This takes into account the spillover effects of R&D in helping build technological absorptive capacity.[102] For example, the Technology Development Foundation of Turkey provides zero-interest loans of up to $1 million to companies that adopt or develop systems for energy efficiency, renewable energy, or cleaner production.[103] In small and low-income countries where there are even more market barriers to technology absorption, public financial support can selectively finance technology absorption in firms, along with related technical consulting and training.

Publicly supported technology diffusion programs bridge gaps in information and know-how among firms, farmers, and public agencies. The most effective programs respond to real demand, address multiple barriers, and include community institutions from the beginning. This creates local buy-in, builds sustainability, and ensures that the programs are compatible with local development goals.[104] In South Africa the Clean Production Demonstration project for metal finishers was successful precisely because it targeted a wide range of issues in parallel—from the lack of information about the advantages of cleaner technologies to the lack of legislation or its enforcement. The demand-driven, project obtained the buy-in of all stakeholders—a broad range of company owners, managers, staff, consultants, regulators, and suppliers—and combined awareness campaigns, training, technical consulting, and financial assistance.[105] In China the government's strategy to improve and diffuse biomass cook stove technology was equally successful because it recognized the systems nature of innovation and was largely demand-driven (box 7.10).

BOX 7.10 *Improved cook stoves designs can reduce soot, producing important benefits for human health and for mitigation*

About 2 billion people in developing countries depend on biomass for heating and cooking. Rudimentary cookstoves in rural areas from Central America to Africa, India, and China release CO_2 along with black carbon (tiny particles of carbon in soot) and products of incomplete combustion (carbon monoxide, nitrogen compounds, methane, and volatile organic compounds). These products pose a serious health hazard. Inhalation of indoor smoke from burning of solid biomass is thought to contribute to the deaths of 1.6 million people a year globally, about 1 million of them children under five years of age.

Recent studies suggest that the power of black carbon as a driver for climate change could be as much as twice what the Intergovernmental Panel on Climate Change previously estimated. New analyses suggest that black carbon could have contributed more than 70 percent of the warming of the Arctic since 1976 and could have been a strong factor in the retreat of Himalayan glaciers.

Given that household solid fuel used in cookstoves in the developing world is responsible for 18 percent of the emissions of black carbon, new cookstove technologies that improve combustion and thus reduce soot and emissions of other gases can have benefits not only for human health but also for mitigation.

A lot of funding has been devoted to support the use of liquefied petroleum gas (LPG) stoves as a cleaner alternative to biomass stoves, mostly by subsidizing LPG, but that has proved ineffective at diffusing the technology widely in developing countries. Even with subsidies, most poor people cannot afford the fuel.

Public programs to introduce improved biomass cook stoves over the past two decades have produced mixed results. In India the government subsidized 50 percent of the cost of 8 million stoves that it distributed. Initially, the program encountered some difficulties because the stove design was not appropriate for the tools and foods used by the population, but during the past five years the government has launched new research to correct these problems. Improved cook stoves are gaining some ground in other countries. In China the government recognized that success hinged on meeting people's needs, and that this could not be achieved through a supply-driven top-down approach. It confined its role to research, technical training, setting manufacturing standards, and reducing bureaucratic impediments to the production and diffusion of new stoves. The enterprise sector was mobilized for local distribution.

Given recent technological progress in biomass cookstoves, their impact on health, and their recently revealed impact on climate change, it is appropriate to massively scale up and commercialize high-quality biomass-based cookstoves. The most effective stoves will be affordable to the poor, adaptable to local cooking needs, durable, and appealing to customers. Project Surya, a pilot evaluation program, is going to undertake the most comprehensive and rigorous scientific evaluation to date on the efficacy of improved cookstoves on climate warming and people's health. The project will support the introduction of new cookstove models in 15,000 households in three different regions of India. By monitoring pollutants through cutting edge sensor technologies, measuring solar heating of the air, and combining these data with measurements from NASA satellites, the project team hopes to observe a "black carbon hole"—the absence of the usual black carbon particles—in the atmosphere over the areas of intervention, and to measure how this impacts regional temperatures and people's health. The study will also improve understanding of how future cookstove programs should address households' needs and behaviors.

A woman cooks with her EnvirofitG-3300 cookstove

Photo credit: Envirofit India.

Sources: Bond and others 2004; Columbia Earthscape, http://www.earthscape.org/r1/kad09/ (accessed May 14, 2009); Forster and others 2007; Hendriksen, Ruzibuka, and Rutagambwa 2007; Project Surya, http://www-ramanathan.ucsd.edu/ProjectSurya.html (accessed August 31, 2009); Ramanathan and Carmichael 2008; Ramanathan, Rehman, and Ramanathan 2009; Shindell and Faluvegi 2009; Smith, Rogers, and Cowlin 2005; UNEP 2008b; Watkins and Ehst 2008.

As already pointed out in chapter 4, government procurement is another market-pull instrument that can create market niches for climate-smart technology, but it relies on good governance and a sound institutional environment. Public purchasing preferences can stimulate climate-smart innovation and technology adoption when the government is a major customer in areas such as wastewater management, construction, and transport equipment and services. Germany and Sweden already include "green" criteria in more than 60 percent of their tenders.[106]

Preventing unmanageable climate change, coping with its unavoidable impacts on society, and meeting global development objectives requires significantly stepping up international efforts at diffusing existing technologies and deploying new ones. For ambitious high-priority initiatives, such as carbon capture and storage, countries can pool their resources, share the risks and share the learning benefits of joint RDD&D. They can create new global funding mechanisms. "Technology-push" policies based on increasing public investments in R&D will not be sufficient to reach our technological objectives. They need to be matched with "market-pull" policies that create public and private sector incentives for entrepreneurship, for collaboration, and to find innovative solutions in unlikely places.

The world must ensure that technological advances find their ways rapidly to countries that have the least ability to adopt them but the most need. Diffusing climate-smart technology will require much more than shipping ready-to-use equipment to developing countries. Namely, it will require building technological absorptive capacity—the ability of the public and private sectors to identify, adopt, adapt, improve, and employ the most appropriate technologies. It will also require creating environments that facilitate the transfer of mitigation and adaptation technologies from one country to the next through channels of trade and investment.

Notes

1. Global Wind Energy Council, http://www.gwec.net/fileadmin/documents/PressReleases/PR_stats_annex_table_2nd_feb_final_final.pdf (accessed April 2009).
2. Metcalfe and Ramlogan 2008.
3. Edmonds and others 2007; Stern 2007; World Bank 2008a.
4. Most integrated assessment models show a demand for no more than 600 gigatons of carbon (2,220 gigatons of carbon dioxide) storage capacity over the course of this century. Published estimates place the potential global geologic storage capacity at about 3,000 gigatons of carbon (11,000 gigatons of carbon dioxide). Dooley, Dahowski, and Davidson 2007.
5. SEG 2007. See, in particular, appendix B, "Sectoral Toolkit for Integrating Adaptation into Planning/Management and Technology/R&D."
6. Heller and Zavaleta 2009.
7. Hulse 2007.
8. Commonwealth Secretariat 2007.
9. McKinsey Global Institute 2007.

"Through my painting I would like to transmit to all the people, including world's leaders, my hope to stop global warming promoting the use of our sun because it is powerful, clean, and practically endless. . . . If we want, we could turn it to be our everyday energy source. Governments and companies should support the use of solar energy and scientists to find the best way so the people can easily use it in their homes, appliances, machines, factories, and vehicles."

—Laura Paulina tercero Araiza, Mexico, age 10

10. Leadbeater and others 2008.
11. Aghion and others 2005.
12. Salter and Martin 2001.
13. De Ferranti and others 2003.
14. Barlevy 2007.
15. Robins and others 2009.
16. Berkhout 2002.
17. UNEP 2008a.
18. A. Gentleman, "Bangalore Turning into a Power in Electric Cars." *International Herald Tribune*, August 14, 2006; Maini 2005; S. Nagrath, "Gee Whiz, It's A Reva! The Diminutive Indian Electric Car Is a Hit on the Streets of London." *Businessworld,* Dec. 19, 2008.
19. The number of patents is often used as a measure of inventive activity, but there can be drawbacks to comparing patents across countries because certain types of inventions are less suited to patenting than others.
20. OECD 2008; Dechezlepretre and others 2008.
21. IEA 2008a; SEG 2007; Stern 2007; Nemet and Kammen 2007; Davis and Owens 2003; PCAST 1999.
22. Based on Inernational Energy Agency (IEA) RD&D statistics including high- and upper-middle-income IEA except for Australia, Belgium, the Czech Republic, Greece, Luxemburg, Poland, the Slovak Republic, and Spain.
23. IEA 2008a.
24. OECD 2008.
25. For example, crops and growing methods often need to be adapted to local climatic, soil, and technological conditions.
26. OECD 2008.
27. Beintema and Stads 2008.
28. Carlsson 2006; Freeman 1987; Lundvall 1992; Nelson 1996; OECD 1997.
29. PCAST 1999.
30. IEA, http://www.iea.org/Textbase/techno/index.asp (accessed December 15, 2008).
31. http://www.energystar.gov/ (accessed December 15, 2008).
32. Milford, Ducther, and Barker 2008; Stern 2007.
33. Guasch and others 2007.
34. De Coninck and others 2007.
35. De Coninck and others 2007.
36. The Millennium Technology Prize, http://www.millenniumprize.fi (accessed February 16, 2009).
37. Jaruzelski, Dehoff, and Bordia 2006.
38. Chesbrough 2003.
39. Newell and Wilson 2005; X Prize Foundation, http://www.xprize.org/ (accessed December 15, 2008).
40. Progressive Automotive X Prize, http://www.progressiveautoxprize.org/ (accessed April 19, 2009).
41. Pneumonia is the leading infectious cause of childhood mortality worldwide; World Bank 2008a.
42. World Bank 2008a.
43. World Bank 2008a.
44. Branscomb and Auerswald 2002.
45. DB Advisors 2008.
46. UNEP 2008a.
47. Nemet and Kammen 2007.
48. National Center for Environmental Research, http://www.epa.gov/ncer/sbir/ (accessed April 2009).
49. Passerelles Pacte PME, http://www.oseo.fr/a_la_une/actualites/passerelles_pacte_pme (accessed November 30, 2008).
50. Goldberg and others 2006.
51. Among the pertinent framework conventions are those on climate change (United Nations Framework Convention on Climate Change, or UNFCCC), biodiversity (Convention on Biological Diversity), desertification (Convention to Combat Desertification), the Ramsar Convention on Wetlands, shared international watercourses, and the Plant Genetic Resources for Food and Agriculture.
52. Brewer 2008; De Coninck, Haake, and van der Linden 2007; Dechezlepretre, Glachant, and Meniere 2007.
53. Doornbosch, Gielen, and Koutstaal 2008; Global Environment Facility, http://www.gefweb.org/ (accessed December 4, 2008).
54. GEF 2008; GEF 2009.
55. The World Bank Carbon Finance Unit, http://wbcarbonfinance.org/ (accessed December 4, 2008).
56. Barrett 2005.
57. De Coninck and others 2007.
58. CCS in Europe, http://ec.europa.eu/environment/climat/ccs/work_en.htm (accessed July 2, 2009).
59. UNESCO Institute for Statistics, http://www.uis.unesco.org (accessed January 18, 2009).
60. Lundvall 2007.
61. Humanitarian Practice Network. http://www.odihpn.org/report.asp?id=2522 (accessed January 14, 2009); Kiang 2006.
62. IPCC 2000.
63. Goldman and Ergas 1997; World Bank 2007a.
64. Juma 2006.
65. World Bank 2005.
66. Watkins and Ehst 2008.
67. UNEP 2008a.
68. Huq, Reid, and Murray 2003.
69. See ecosystems-based management in chapter 3.
70. SEG 2007.
71. Schneider and Goulder 1997; Popp 2006; also see chapter 4.

72. Hicks 1932.

73. Hayami and Ruttan 1970; Hayami and Ruttan 1985; Ruttan 1997; Jaffe, Newell, and Stavins 2003; Popp 2002.

74. Newell, Jaffe, and Stavins 1999.

75. Jaffe, Newell, and Stavins 2003.

76. Taylor, Rubin, and Hounshell 2005.

77. Weinert, Ma, and Cherry 2007; the Climate Group 2008; Chang Chieh and Chen 2008; C. Whelan, "Electric Bikes Are Taking Off." *New York Times*, March 14, 2007, http://www.time.com/time/world/article/0,8599,1904334,00.html (accessed July 5, 2009).

78. Bernauer and others 2006.

79. World Bank 2007b.

80. de Chavez and Tauli-Corpuz 2008.

81. World Bank 2008b; Scarpetta and Tressel 2004.

82. Matuschke and Qaim 2008.

83. These countries are Argentina, Bangladesh, Brazil, Chile, China, Colombia, Arab Republic of Egypt, India, Indonesia, Kazakhstan, Malaysia, Mexico, Nigeria, the Philippines, South Africa, Thailand, República Bolivariana de Venezuela, and Zambia. World Bank 2008c.

84. World Bank 2008c.

85. Steenblik 2007.

86. IMF 2008.

87. Goldberg and others 2008.

88. Brewer 2008.

89. UNCTAD 2005.

90. Maskus 2004; Hoekman, Maskus, and Saggi 2004; Lewis 2007.

91. Barton 2007.

92. Branstetter, Fisman, and Fritz Foley 2005; Deloitte 2007.

93. Dedigama 2009.

94. ICTSD 2008.

95. Barton 2007; Lewis 2007; ICTSD 2008.

96. Hoekman, Maskus, and Saggi 2004.

97. World Bank 2007b.

98. Barton 2007.

99. ICTSD 2008.

100. Baker and Shittu 2006; Jaffe, Newell, and Stavins 2003; Schneider and Goulder 1997; Popp 2006.

101. Nelson 1959; Arrow 1962.

102. Cohen and Levinthal 2009.

103. Technology Development Foundation of Turkey, http://www.ttgv.org.tr/en/page.php?id=35 (accessed March 5, 2009).

104. IPCC 2000.

105. Koefoed and Buckley 2008.

106. Bouwer and others 2006.

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Overcoming Behavioral and Institutional Inertia

Many policies to address adaptation and mitigation are already known. Secure property rights, energy-efficient technologies, market-based eco-taxes and tradable permits—all have been piloted and studied over decades. But implementing them still proves difficult. Their success relies not just on new finance and new technology but also on complex and context-specific social, economic, and political factors normally called institutions—the formal and informal rules affecting policy design, implementation, and outcomes.[1]

Values, norms, and organizational arrangements can make policy change hard. Experiences frame current and future action. Patterns of individual and organizational behavior die hard even in the face of new challenges. And political traditions constrain policy choices. Some examples. Most countries still gear policies and regulatory institutions to ensure the supply of energy—not to manage demand. Pollution taxes in economies where pollution is not considered a public bad will generate resistance from decision makers and the public alike. And economic interests can hinder the deployment of energy-efficient technologies.[2]

The examples show another dimension of the urgency of tackling climate change. In addition to the inertia of climate, technology, and capital stocks, policy has to overcome institutional inertia. Institutions tend to be sticky—once in place and accepted, they can limit policy change and future choices.[3]

Institutional inertia has three implications for climate-smart development policy. First, institutional change should be a priority. Success will hinge on reshaping the institutional framework supporting interventions. Second, institutional reform pays off. Addressing the institutional determinants of climate policy can ensure the effectiveness and sustainability of interventions, maximize the impact of finance and technology, and yield additional development payoffs. Third, institutional change is feasible. Increasing gender inclusion, recognizing indigenous peoples' rights, reforming property rights, and shaping individual incentives can be demanding, but they are not impossible. Many of these changes can be accomplished without technological

Key messages

Achieving results in tackling the climate challenge requires going beyond the international mobilization of finance and technology, by addressing the psychological, organizational, and political barriers to climate action. These barriers stem from the way people perceive and think about the climate problem, the way bureaucracies work, and the interests shaping government action. Policy change requires shifting political incentives and even organizational responsibilities. And it requires the active marketing of climate policies, tapping into social norms and behaviors, in order to translate the public's concern into understanding and understanding into action—starting at home.

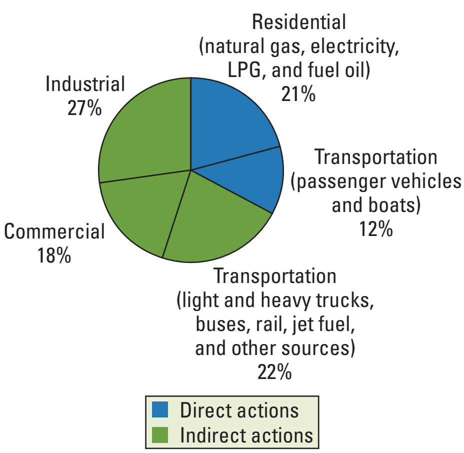
breakthrough or additional finance. More important, many of these interventions fall within the realm of national or even local policy—there is no need for a global climate deal to enhance press freedom, for example, or the voice of civil society.[4]

This chapter discusses the behavioral, organizational, and political determinants of the institutional inertia hindering climate-smart development. It shows how these forces affect the implementation of new policies and hamper their success in both developed and developing countries. And it argues that overcoming inertia requires reconsidering the scope and quality of government's role. We start with individuals' minds.

Harnessing individuals' behavioral change

Understanding the drivers of human behavior is essential for climate-smart development policy. First, myriad private acts of consumption are at the root of climate change. As consumers, individuals hold a reservoir of mitigation capacity. A large share of emissions in developed countries results directly from decisions by individuals—for travel, heating, food purchases. U.S. households account for roughly 33 percent of the nation's carbon dioxide (CO_2) emissions—more than U.S. industry and any other country bar China (figures 8.1 and 8.2).[5] If fully adopted, existing efficiency measures for households and motor vehicles could produce energy savings of almost 30 percent—10 percent of total U.S. consumption.[6] Second, individuals drive the larger processes of change in organizations and political systems. Particularly in democratic countries, much government action is the result of citizen and voter pressures to act. Third, when designing and implementing policy, decision makers apply the same mental processes as other individuals.

Figure 8.1 The direct actions of U.S. consumers produce up to one-third of total U.S. CO_2 emissions



Sources: EIA 2009; EPA 2009.
Note: LPG = liquified petroleum gas.

The debate about changing individual behavior has focused on market mechanisms. Better pricing of energy and costing of scarce resources can steer individuals away from carbon-intensive consumption and encourage them to preserve endangered habitats and manage ecosystems better. But the drivers of consumption by individuals and groups go beyond prices. Many cost-effective energy-efficient technologies have been available for years. "No-regret" investments such as improving building insulation, addressing water leaks, and limiting building in flood-prone areas yield benefits beyond mitigation and adaptation. So, why haven't they been adopted? Because concern does not mean understanding, and understanding does not necessarily lead to action.

Concern does not mean understanding

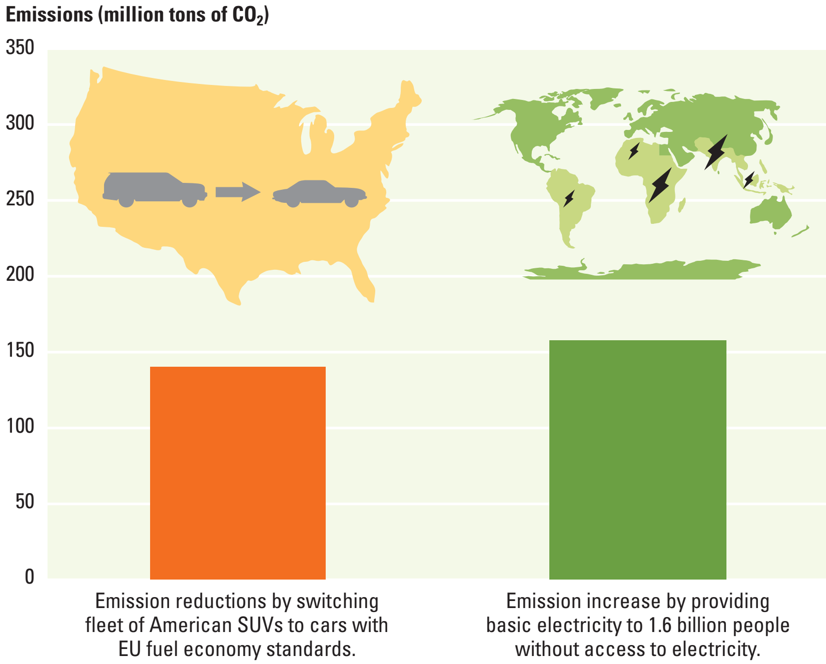
Over the past decade, awareness of climate change has grown without translating into widespread individual action.[7] Indeed, flying, driving, holidaying abroad, and using household appliances have increased globally.[8]

What explains the disconnect between perception and action? Concern about climate change does not necessarily mean understanding its drivers and dynamics or the responses needed. Polls show that the public admits to remaining confused over climate change's causes and solutions.[9] This "green gap" in public attitudes stems partly from how climate science is communicated and how our minds (mis)understand climate dynamics (box 8.1).[10]

Standard information-deficit models assume that when people "know" more, they act differently.[11] People today are exposed to lots of information on the causes, dynamics, and effects of climate change. This information has clearly increased concern, but it has not led to action.[12] Why? Because information can produce misleading feelings of "empowerment," which then turns into ambivalent powerlessness when paired with more "realistic" messages. Conveying urgency by stressing the unprecedented nature and scale of the problems can result in paralysis.[13] Similarly, playing up the multistakeholder nature of mitigation and adaptation is a reminder that the solution rests with no single actor, resulting in a general feeling of helplessness and disempowerment.[14] This might explain why, in developed countries where information on climate change is more readily available, people are less optimistic about a possible solution (figure 8.3).

To produce action, awareness needs to be grounded in clear information from trustworthy sources. The way climate change science is communicated to the public can complicate things. Scientific debate evolves through testing and cross-checking of theories and findings. News coverage can veer from one extreme to another, resulting in more confusion for the public, which may perceive the debate not as scientific progress but as a proliferation of contradictory opinions.[15] Moreover, the media's need to present "balanced" stories has given disproportionate coverage to climate science contrarians lacking scientific expertise and standing.[16]

Figure 8.2 Small local adjustments for big global benefits: Switching from SUVs to fuel-efficient passenger cars in the United States alone would nearly offset the emissions generated by providing energy to 1.6 billion more people



Source: WDR team calculations based on BTS 2008.

Note: Estimates are based on 40 million SUVs (sports utility vehicles) in the United States traveling a total of 480 billion miles (assuming 12,000 miles a car) a year. With average fuel efficiency of 18 miles a gallon, the SUV fleet consumes 27 billion gallons of gasoline annually with emissions of 2,421 grams of carbon a gallon. Switching to fuel-efficient cars with the average fuel efficiency of new passenger cars sold in the European Union (45 miles a gallon; see ICCT 2007) results in a reduction of 142 million tons of CO_2 (39 million tons of carbon) annually. Electricity consumption of poor households in developing countries is estimated at 170 kilowatt hours a person-year and electricity is assumed to be provided at the current world average carbon intensity of 160 grams of carbon a kilowatt-hour, equivalent to 160 million tons of CO_2 (44 million tons of carbon). The size of the electricity symbol in the global map corresponds to the number of people without access to electricity.

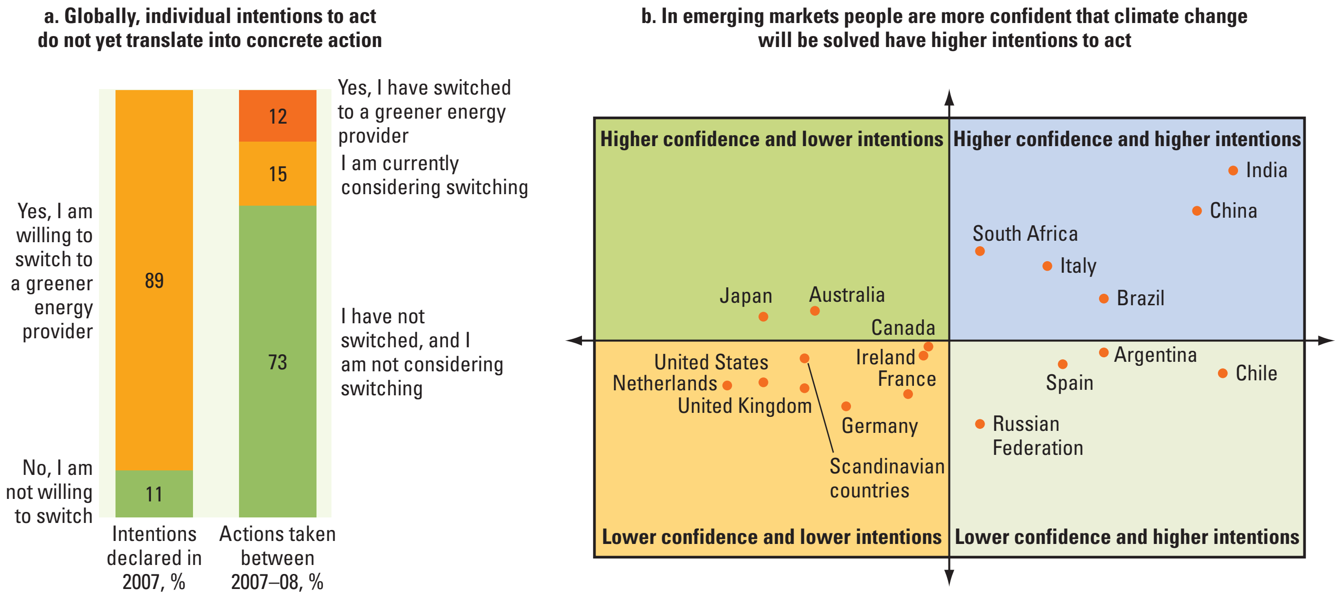
BOX 8.1 *Miscommunicating the need for climate action*

Reporting on climate change can have the counterproductive effect of immobilizing people. A linguistic analysis of media coverage and environmental groups' communications on climate change found that the more people are bombarded with words or images of the devastating, quasi-biblical effects of climate change, the more likely they are to tune out and switch off. Depicting climate change as "scary weather" can set up a pernicious set of reactions, because people tend to see weather as being outside human control. They cannot prevent or change it. They prepare for it, adjust to it, or move away from it. And focusing on the long time lines and scale of climate change encourages them to think "it won't happen in my lifetime" and "there's nothing one can do."

Stressing the large scale of climate change while telling people they can solve it through small actions (like changing a light bulb) creates a disconnect that undermines the credibility of the messages and encourages people to think that action is meaningless. A typical global warming news story—outlining the scientific proof, stressing the severe consequences of inaction, and urging immediate steps—can lead people to think that preventive action is meaningless.

Source: Retallack, S., www.opendemocracy.net/globalization-climate_change_debate/ankelohe_3550.jsp (accessed July 17, 2008).

Figure 8.3 Individuals' willingness to respond to climate change differs across countries and does not always translate into concrete actions



Source: Accenture 2009.

Note: The 2009 Accenture Climate Change Survey was conducted with a sample of 10,733 individuals in 22 developed and emerging economies. The sample was representative of the general population in developed countries and urban populations in developing countries. Panel a: Respondents were asked about their willingness to switch to a greener energy provider if the provider offered services that help reduce carbon emissions. Intentions did not translate into action, with most respondents staying with their old energy provider. Panel b: Based on the questionnaire, countries were ranked on two criteria—confidence and intention. Confidence measured the individual's optimism about the ability of individuals, politicians, and energy providers to find a solution. Respondents in emerging economies generally were more optimistic about humankind's ability to take action to solve global climate change.

The media, in search of punchy stories, tend to shy away from the scientific community's careful wording to express uncertainty. Readers then face messages lacking scientific caution and containing strong appeals that might then be refuted by other similarly strongly worded statements, hampering the perceived reliability of the information source. In addition to confusing the public (and policy makers) about causes, impacts, and potential solutions, different types of framing can antagonize individuals and induce a sense of guilt, and even of being vilified, when the problem of consumption is characterized as a problem of consumers.[17] This can lead people to reject the message rather than act on it.

An added challenge in moving from concern to understanding has to do with how the mind perceives the problem. The dynamics of climate change stretch our mental capacities in several ways.[18] Psychological research shows that individuals are ill equipped to deal with multiple-cause problems.[19] Simplifying problems by adopting single-cause explanations in turn leads to searching for individual solutions and focusing on (often nonexistent) technological silver bullets. The inertia affecting our responses can be linked to a limited understanding of stock-and-flow relationships, which characterize the concentration, removal, and stabilization of greenhouse gases. The fact that even the most drastic and sudden emission reductions will not prevent further warming, or make the need for adaptation disappear in the short and medium term, is something we struggle with and, without careful explanation, simply do not understand (box 8.2).[20]

Understanding does not necessarily lead to action

Knowledge is mediated through value systems shaped by psychological, cultural, and economic factors that determine whether we act or not. Again the idea here is not that we are irrational but that we need to understand better how we make decisions. Our evolution as a species has shaped the way our brains work. We are particularly good at acting on threats that can be linked to a human face; that present themselves as unexpected, dramatic, and immediate; that involve obvious links to human health; that challenge our moral framework, provoking visceral reactions; or that evoke recent personal experience.[21] The slow pace of climate change as well as the delayed, intangible, and statistical nature of its risks, simply do not move us (box 8.3).

Behavioral economics shows that features of human decision making under uncertainty constrain our natural instinct to adapt.[22] We tend to underestimate cumulative probabilities (the sum of the probabilities of an event occurring over a period of time), which explains why building continues in areas prone to fires, flooding, and earthquakes. People strongly favor the status quo and prefer to make only small incremental adjustments to it. They are at a loss when measuring achievements is difficult, as in disaster preparedness, where there are no clear counterfactuals. We are "myopic decision makers" who strongly discount future events and assign higher priorities to problems closer in space and time. For instance, the public tends to be mobilized by visible environmental problems (urban air pollution) but not by less visible ones (species extinction). Individuals rank climate change lower than other environmental issues perceived as closer to home (figure 8.4).[23]

Even if people were indeed fully rational, knowledge would not necessarily lead to action. Their "finite pool of worries" might prevent them from acting on existing information because they prioritize basic needs such as security, shelter, and the like.[24] They

BOX 8.2 *Misunderstandings about the dynamics of climate change encourage complacency*

Support for policies to control greenhouse gas emissions is hampered by people's limited understanding of climate change's dynamics. Experiments show that a majority of people misunderstand the basic stock-and-flow nature of the problem: they believe that stabilizing emissions near the current rates would stabilize concentrations of greenhouse gases in the atmosphere and halt climate change. Instead the flow of emissions is best compared to the flow of water entering a bathtub: as long as the inflow is greater than the outflow, the level of water in the tub will rise. As long as emissions exceed the amounts that can be taken up by terrestrial and aquatic systems, concentrations of greenhouse gases will rise. Even for those who consider climate change a priority, a misunderstanding of the stock-and-flow process favors wait-and-see policies, limiting public pressure and political will for active policy to stabilize the climate. These misperceptions can be corrected through communication strategies that use analogies, such as the bathtub example.

Sources: Sternman and Sweeney 2007; Moxnes and Saysel 2009.

BOX 8.3 *How risk perceptions can sink policies: Flood risk management*

The impulse to address risk is fundamentally related to perceptions of the seriousness and likelihood of impacts.

The perception of probabilities and the methods people tend to use to estimate those probabilities can be misleading. For example, people evaluate the likelihood of an event occurring in a given place based on how similar the latter is to locations where such events normally occur.[a] The availability of recent and vivid memories of an event also leads people to overestimate its probability. It has been observed that often people overestimate the likelihood of low-probability events and underestimate the likelihood of high-probability events. People are notoriously more scared of sitting in a plane than in a car (although the risk of a deadly car accident event is significantly higher). Similarly, rare natural disasters such as tsunamis, generate more concern than more frequent events such as storm surges.[b]

These behavior patterns were identified among farmers and policy makers in Mozambique after the 2000 floods and during the subsequent resettlement program implemented by the government. Farmers (more than policy makers) showed a bias toward the status quo: for farmers, actions to adapt to climate factors are often weighted against risks of negative outcomes. The decision to move to a safe area on higher ground, for example, entails the risk of losing one's livelihood or community. The decision to plant a drought-tolerant crop can lead to the risk of having a lower harvest, if the rains are plentiful. Farmers wanting to avoid personal responsibility for negative outcomes will avoid making new choices. By contrast, policy makers can gain personal credit for avoiding a negative outcome, but only if they take visible action—say, by helping farmers survive through resettlement.

Different stakeholders view probabilities differently. Policy makers in Maputo tend to associate the Limpopo River floodplain with flood risk alone. For the people living there, however, life in the floodplain is defined by many other factors in addition to climate risks. Relative to local farmers, these policy makers have a propensity to overestimate climate-related risks. Unless risk analysis and communication are adequately factored in, major differences in perceptions of risk can impede successful policy design and implementation.

Sources: Patt and Schroter 2008.
a. Tversky and Kahneman 1974.
b. Kahneman and Tversky 1979.

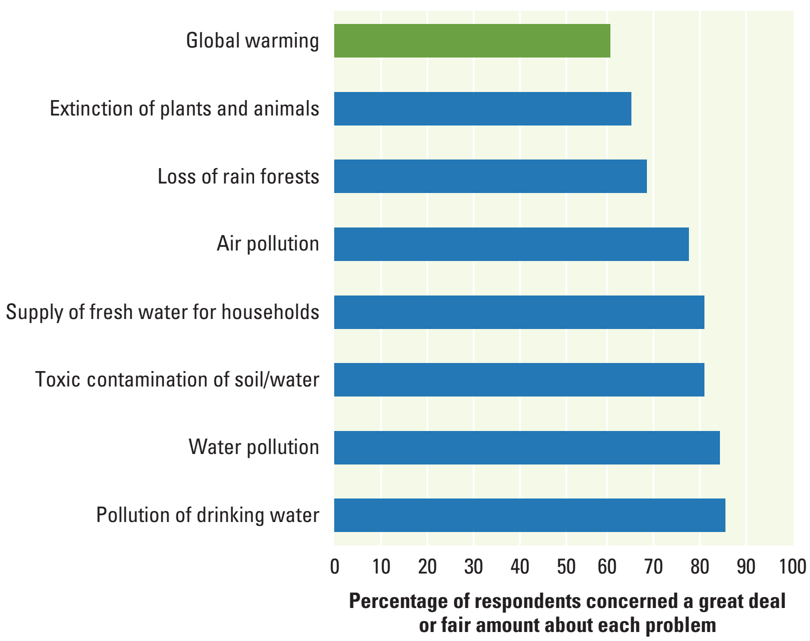
also assess both the market and nonmarket costs of decisions. The nonmarket costs of acting on information that challenges core value systems (such as calls for resettlement and migration or for limiting consumption patterns) can be high. Indeed, the very act of interpreting or mediating additional information is costly. For a household having to decide whether to keep rebuilding on a flood-prone area, or for a local official designing and enforcing building codes in low-lying coastal areas, the transaction costs can be substantial. Moreover, both mitigation—and, very often, adaptation—present themselves as tragedies of the commons requiring collective action. Rational and self-interested individuals face structural disincentives to cooperate in solving these problems.[25] Cooperation in these conditions requires the payoffs to be clear—obviously not the case with climate-change impacts and responses.[26]

Understanding barriers to behavior change also requires going beyond psychological explanations based on the individual as a unit of analysis—and embracing the way social factors influence perceptions, decisions, and actions. People naturally tend to resist and deny information that contradicts their cultural values or ideological beliefs. This includes information that challenges notions of belonging and identity as well as of rights to freedom and consumption. Notions of needs and the priorities deriving from them are socially and culturally constructed.[27] This might explain why awareness of environmental problems normally increases with wealth, but concern about climate change does not (figure 8.5).[28] Individuals (and nations) with higher incomes (and higher carbon dioxide emissions) may disregard global warming as a way to avoid incurring the potential costs of solutions associated with lower levels of consumption and lifestyle changes.[29]

People also construct and reconstruct information to make it less uncomfortable, leading to strategies of socially organized denial that shape the way societies and governments interpret and respond to climate change.[30] The evolution of standard narratives about climate change provides an example. Focusing on country emissions rather than per capita emissions can lead people living outside the big emitters to minimize their responsibility and rationalize their failure to act. Drastic calls for the need for an international response tend to play down the fact that domestic action will be required in any case. And uncertainty about dynamics and impacts can be overplayed to justify inaction.

These forms of denial are not abstract—nor are they confined to climate policy. Similar processes operate at various levels of day-to-day decision making, and addressing them is part of solving crucial development challenges, such as reducing the spread of HIV-AIDS or the incidence of common water- and sanitation-related diseases. Rather than an aberration, denial needs to be considered a coping strategy deployed by individuals and communities facing unmanageable and uncomfortable events. Resistance to change is never simply the result of ignorance—it derives from individual perceptions, needs, and wants based on material and cultural values.

Figure 8.4 Climate change is not a priority yet



Source: Gallup Poll, www.gallup.com/poll/106660/Little-Increase-Americans-Global-Warming-Worries.aspx (accessed March 6, 2009).

Note: Respondents were asked the following question: " I'm going to read you a list of environmental problems. As I read each one, please tell me if you personally worry a great deal, a fair amount, only a little, or not at all." Results are based on phone interviews on March 5–8, 2009. The sample comprised 1,012 U.S. citizens aged 18 and older.

Encouraging behavioral change

Policy makers need to be aware of these barriers to action and treat policy options accordingly. Three policy areas are relevant here: communications, institutional measures, and social norms.

From information to communication. Information, education, and awareness raising, as carried out so far, are at best not enough to spur people to action and at worst counterproductive. This calls for a different approach to providing information about climate change.[31] First, the information-driven approach must shift to an audience-centric one in communicating climate change. Both scientists and the media need to work together to enhance the salience of their messages. Second, as in other policy areas, such as AIDS prevention, this shift should entail a marketing approach to communication, where the individual is considered not merely the passive receiver of information but an active agent in both causes and solutions (box 8.4).

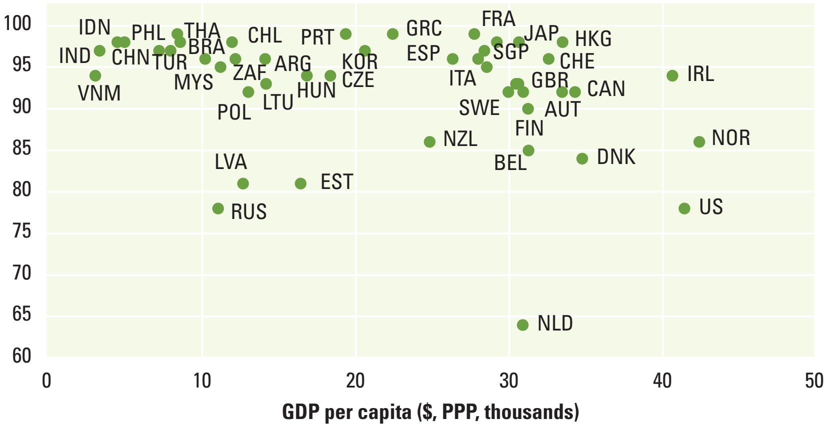
Well-designed communication campaigns that address individuals as members of a local community—and not as powerless members of an unmanageably large group—can empower them to act. This treatment can help make a global phenomenon personally relevant and immediate, and accentuate the local and individual ownership of the solutions. It is important to limit "greenwash" in business and government—the gap between agreeing publicly on the reality of climate change while doing nothing about it—to avoid confusion and public backlash (box 8.5).

A controversial question is whether detailed public understanding of highly complex issues such as climate change is feasible, even necessary, for effective policy making. The answer is no, or at least not always. Much policy making is based on technicalities fully ignored by the public. Few people understand the intricacies of trade policies affecting the price of the food they buy and eat, or produce and sell. Where buy-in is necessary, it is often encouraged through other means.

Yet discounting information and public awareness as unnecessary would be a mistake. Recent work has highlighted that information is key for the public to back costly measures. The benefits of providing more accurate information about people's consumption decisions—say, through

Figure 8.5 Concern about climate change decreases as wealth goes up

Percentage of respondents who consider climate change a serious problem



Source: Sandvik 2008.

Note: Public concern about global warming is expressed as percentage based on respondents who consider climate change a serious problem. It was taken from a global online survey conducted by ACNielsen in 2007 on consumer attitudes toward global warming. Respondents from 46 different countries were asked how serious a problem (on a scale from 1 to 5) they thought global warming was. The base population is respondents who have heard or read about global warming.

BOX 8.4 *End-to-end community engagement for landslide risk reduction in the Caribbean*

A new way of delivering real landslide-risk reduction to vulnerable communities was piloted by MoSSaiC, a program aimed at improving the management of slopes in communities in the eastern Caribbean. MoSSaiC identifies and implements low-cost, community-based approaches to landslide-risk reduction, in which community residents indicate areas of perceived drainage problems before assessing options for reducing landslide risk by managing surface water.

The activities? Managing surface water in all forms (roof water, grey water, and overland flow of rainfall water), monitoring shallow groundwater conditions, and constructing low-cost drain systems. All the work is bid out to contractors in the community. This end-to-end community engagement encourages participation in planning, executing, and maintaining surface water management on high-risk slopes. It produces a program owned by the community rather than imposed by the agency or government.

MoSSaiC has lowered landslide risk by offering the community employment and risk awareness—and has taken a participatory approach to rolling out the program to other communities. The program shows that changing community views of hazard mitigation can enhance community perceptions about climate risks. It also establishes a feedback loop between project inputs and outputs, with more than 80 percent of funds spent in the communities, allowing communities and governments to establish a clear link between risk perceptions, inputs, and tangible outputs.

Source: Anderson and Holcombe 2007.

BOX 8.5 *Communicating climate change*

How an issue is framed—the words, metaphors, stories, and images used to communicate information—determines the action. Frames trigger deeply held world views, widely held assumptions, and cultural models in judging the message and in accepting or rejecting it accordingly. If the facts don't fit the frames, the facts are rejected, not the frame.

Based on that understanding, it can be decided whether a cause is best served by repeating or breaking dominant discourse, or by reframing an issue using different concepts, languages, and images to evoke a different way of thinking and facilitate alternative choices.

Applying this approach to communications on climate change could take many forms:

- Place the issue in the context of higher values, such as responsibility, stewardship, competence, vision, and ingenuity.
- Characterize mitigation actions as being about new thinking, new technologies, planning ahead, smartness, farsightedness, balance, efficiency, and prudent caring.
- Simplify the model, analogy, or metaphor to help the public understand how global warming works—a conceptual hook to make sense of information and set up appropriate reasoning (instead of the "greenhouse gas effect" call it a "heat trap").
- Refocus communications to underscore the human causes of the problem and the solutions that exist to address it, suggesting that humans can and should act to prevent the problem now.
- Evoke the existence and effectiveness of solutions upfront.

Source: Lorenzoni, Nicholson-Cole, and Whitmarsh 2007.

carbon labeling and smart meters—have long been proven. A U.S.-based survey found that one of the main factors responsible for the public's negative perceptions of cap-and-trade schemes is not the fear of additional costs but the limited knowledge of their effectiveness, reducing public trust in them.[32] Similarly, opposition to environmental taxes seems to fall once the public fully understands that they are a way not simply to raise money but to change behavior.[33]

Institutional measures. Beyond communication, a key issue for climate policy is designing interventions that take into account the social and psychological constraints to positive action. Effective adaptation interventions should reduce the transaction costs for individuals in making decisions and enhance the ownership of the information available. This requires that adaptation strategies be informed by community perceptions of risk, vulnerability, and capacity (see box 8.5). Institutionalizing participatory self-assessments for national and local disaster preparedness, adaptation planning, and mitigation can be useful here.

Limiting the tendency of individuals to discount the value of the future is another area for action. Although discounting the future is an innate mental propensity, it varies with social characteristics and external pressures. Evidence from Peru shows that farmers with limited access to credit and insurance and with weak property rights have higher discount rates—and that steeper discounting increases individuals' incentives to deforest.[34] Institutional reforms to improve credit access and property rights can affect inner behavioral drivers of discounting. So can education (box 8.6).

Similarly, interventions that rely on individuals and businesses facing up-front costs but gaining long-term benefits (such as those deriving from energy-efficiency investments) should consider providing immediate payoffs in tax rebates or subsidies. Giving private actors a sense of long-term policy direction is also useful. An international survey of business leaders conducted in 2007 found that 81 percent of those polled believed that the government needs to provide clear long-term policy signals to help companies find the incentives to change and plan investments.[35] (Ways for government to signal long-term direction are explored below.)

Climate policy should also heed the tendency of individuals to favor local, visible, and privately securable outcomes. Mitigation actions produce benefits that are global and diffuse, and the direct benefits of adaptation measures may or may not be immediately apparent, based on the type of climate event under consideration and on the rate of change. The public at large may perceive these benefits as distant and uncertain. It is the role of institutions to communicate clearly the direct benefits and co-benefits of both adaptation and mitigation, particularly emphasizing those that involve human health, a subject that moves people.

Improved cost-benefit tools can encourage public and private decision makers to act more decisively. The estimation of costs and benefits of energy-efficiency projects often does not include nonenergy co-benefits. These include the public health benefits from cleaner air and water, the possibly greater comfort of building occupants, and higher labor productivity.[36] Switching from fossil to renewable energy can create jobs.[37] Case studies in manufacturing conclude that these benefits can be considerable, sometimes equivalent to the value of the energy savings alone.[38] So the time frame for investment paybacks can be substantially shortened, providing better incentives to invest. Similarly, earmarking revenues from carbon or energy taxes can increase the visibility of benefits of mitigation. Although fiscal earmarking is deemed economically inefficient, it can increase political acceptance of new taxes, because the public sees clearly where the money goes.

BOX 8.6 *Inserting climate education in school curricula*

Education can help drive behavioral change. In the Philippines the president signed into law the National Environmental Awareness and Education Act of 2008, which promotes the integration of climate-change education in school curricula at all levels. The 1998 education reforms in Lebanon incorporated environmental studies, including climate change, into science, civic, and geography classes. In 2006 the U.S. Environmental Protection Agency created a climate-change-based educational resource for high school students, allowing them to calculate emissions inventories. In 2007 Canadian provinces committed to include climate change in their school curricula. Under Australia's Third National Communication on Climate Change the government provides support and develops material to promote climate change education, such as a school resource kit developed by the Australian Greenhouse Office.

Incorporating climate change education in school curricula is a first step. Developing a new cadre of professionals to tackle the complex problems posed by climate change is equally important (see chapter 7). Finally, an educated citizenry is essential to facilitate change. Research shows that students and the general public hold onto misunderstandings about various aspects of climate change, the greenhouse effects, and ozone layer depletion.[a] To address these shortcomings, the public must be informed about climate change accurately and systematically.

Source: Hungerford and Volk 1990; Kastens and Turrin 2006.

a. Gautier, Deutsch, and Rebich 2006.

Social norms. Social norms are the patterns of behavior that most people approve of—the yardsticks they use to assess the appropriateness of their own conduct. In shaping human action, social norms can achieve socially desirable outcomes, generally at a fairly low cost. The basic idea is that people want to act in a socially acceptable way and tend to follow the lead of others, particularly when the others are numerous and are perceived as similar.

Social norms have a particularly strong impact under conditions of uncertainty.[39] When looking for clues about how to behave, people rely on what others do. Appeals for proenvironmental behavior based on social norms are superior to traditional persuasion. Not littering is an example.

A climate-relevant example comes from a psychological experiment on California residents to test the impact of social norms on energy consumption.[40] The average household energy consumption was communicated through energy bills to one group of high-energy households and two groups of low-energy households. This set the social norm. One group of low-energy households received positive feedback for their energy consumption statement (a smiley face), conveying approval of their energy footprint. High-energy households were shown their use coupled with negative feedback (a sad face) to convey disapproval. The result: high-energy households reduced consumption, and low-energy ones maintained their lower-than-average consumption. The third group—low-energy households initially exposed to the social norm but receiving no positive feedback about their behavior—increased their consumption to reach the average. Utilities eager to reduce energy use have adopted the approach in 10 major metropolitan areas in the United States, including Chicago and Seattle.

Harnessing the power of social norms implies increasing the visibility of behavior and its implications. Individual decisions and actions that have a bearing on energy consumption today are largely invisible to the public and even to restricted circles of family and friends. In these cases human action cannot benefit from patterns of reciprocity, peer pressure, and group behavior normally at play in more visible cases of behavior change and compliance, such as compliance with traffic control.

Research on cooperation leads to the same conclusion. Unless information about other players' behavior is available, people tend not to cooperate.[41] Farmers within a river basin should receive information not only about their water use but also about whether they are below or above the standard set by their peers. Residents of flood-prone areas can be encouraged to adopt protection measures by exposing them to the rapid uptake of such measures by others in their community. Conversely, appeals stressing that too many people have not yet installed basic energy-efficiency measures are bound to lead to even less adoption of such measures, not more.

Social norms can complement traditional public policy approaches and measures, such as regulation, taxation, and pricing. Thinking about group behavior can ameliorate the impact of these measures, opening opportunities for combining different instruments. But some policies based on economic incentives might do more harm than good by weakening the effect of social norms. Pricing pollution or emissions might give polluters the impression that it is all right to pollute, as long as they pay their fair share. Similarly, imperfectly enforced regulation, or perceptions that formal rules can be eluded, can favor more self-interested behavior and weaken cooperation.[42]

More radical calls for social norms focus on alternative parameters of progress, such as stressing a shift toward notions of well-being decoupled from consumption.[43] And political opposition to instruments such as green taxes can be overcome through tax-rebate schemes—in Sweden, for example, very high tax rates on nitrogen oxide emissions from power producers were politically acceptable because taxes were fully rebated to producers on the basis of how much electricity they produced.[44]

These measures are obviously not enough to ensure the success of climate policy. But they might well prove necessary. Encouraging behavior change for mitigation and adaptation goes beyond providing additional information, finance, or technology. Traditional measures can be complemented by alternative interventions, often at low cost. Rather than simply treat these social and psychological drivers of behavior as barriers to adaptation and mitigation, policy makers can use them to build more effective and sustainable policy.

Bringing the state back in

Over the past 30 years the role of the state has been cut back in various domains key to addressing the climate challenge, such as energy research. The retreat from direct intervention occurred with a switch from "government" to "governance" and an emphasis on the state's role in steering and enabling the private sector.[45] This general trend hides a complex picture. Twentieth-century Europe saw various forms and degrees of state capitalism. The rise of East Asian economies, including China's, demonstrated the preeminence of the state in "governing the market" to deliver the most successful example of accelerated development.[46] Most recently, the 2008 financial crisis showed the pitfalls of deregulation and unrestrained markets—and triggered renewed emphasis on bringing back the state.

Climate change requires public interventions to address the multiple market failures driving it—the failures of pricing; of research and technology development; and of coordination and collective action, global, national, and local.[47] As providers of public goods and correctors of externalities, governments are expected to address these market failures. But there are more specific drivers of government intervention.

First, the private sector's role in solving the climate challenge is crucial, but overplaying it would be unwise. Despite the enthusiasm for the private sector's contribution to major investment projects in the 1980s and 1990s, private participation in infrastructure remains limited. Although the bulk of the additional investment and financing needed for climate-change mitigation and adaptation is expected to come from the private sector, government policies and incentives will be fundamental.[48] Moreover, energy providers and electric utilities are usually government-owned or government-regulated private corporations. Changing the mix of generation facilities may require subsidies and up-front fixed-capital investments. Business certainly has an incentive to secure the attractive returns from investments in energy efficiency, but, as discussed in chapter 4, market barriers are likely to require government action. Where high costs of new technology (low-emission vehicles or solar electricity generation, for example) are constraining supply and demand, a range of government incentives may be required to expand markets.

Second, mitigation and adaptation are both likely to increase public spending. Auctioning emission permits or taxing carbon generates revenues. Keeping expenditure flat would require government to deliver complete tax rebates or full revenue recycling. But such fiscal neutrality might be perceived as a luxury in countries looking for cash to fund new public investments for adaptation and for new energy infrastructure while containing their fiscal deficits. As chapter 7 highlights, governments need to expand their already significant role in technology research, development, and demonstration. Governments can change incentives, either by subsidizing investments with wider social benefits that markets tend to undersupply (such as risky energy R&D) or by taxing or regulating actions that are socially harmful.

Third, the greater frequency and severity of extreme weather events will pressure governments to enhance their insurance function. As chapter 2 notes, insurance markets can go only so far in securitizing climate risks. Developed-world insurance systems are already stretched in dealing with rising hazards along the U.S. and Japanese coasts, in upper-middle-income Caribbean islands, and on floodplains in northern Europe. Climate change is expected to exacerbate insurability problems, requiring renegotiation of the boundary between private and public insurance systems. Governments will face pressures to become insurers of last resort for more of the population and for more damages. In parallel, they will need to address the moral hazards inducing people to make bad choices because of insurance.

Fourth, governments will have to do more as knowledge and learning platforms, particularly around adaptation.[49] As chapter 7 argues, this will require more investments in R&D and more effective markets for technology innovation. It will also require transforming meteorological services into climate services, overseeing the distribution of information at different levels, and using international regimes and organizations as policy-learning arenas for governments to learn from each other and adapt policy to local circumstances.

Fifth, as the prime repositories of political legitimacy, governments will be expected to steer the private sector, facilitate community action, and establish the optimal decentralization of adaptation and mitigation decision making and action. On top of steering, governments will be expected to play an “ensuring” function: guaranteeing that targets and goals are achieved through new emphasis on regulation, taxation, long-term planning, and communication.[50]

None of this means that the size of the state needs to expand—government size is not always associated with better provision of public goods.[51] Instead, it is about recognizing, as chapter 2 points out, that the added challenges of climate change will also increase the cost of government failures. Addressing these challenges will require broadening government objectives and agendas and stepping up the type, scope, and quality of government interventions.

Toward climate-smart government

Governments will need to review the way they operate if they are to successfully address the climate challenge. As attention shifts from identifying the causes and impacts of climate change to devising responses, government setups will need rearranging.[52]

In most countries no single government agency can fully control climate-change policy; relevant mandates, responsibilities, and constituencies are spread over different ministries. Yet few governments have an agency capable of enforcing carbon budgets. In addition, the time frames of climate impacts and required responses go well beyond those of any elected administration. And bureaucracies are not quick learners.[53] Because of the novelty of climate change as a public policy domain and because of the urgency of action, policy makers need to prepare for a degree of failure—and to learn from it. These problems have been identified in the literature as the main drivers of failures to act in organizations.[54]

Government effectiveness will be critical to leveraging the impact of adaptation funding. As chapter 6 notes, most adaptation activities today are implemented through stand-alone and disconnected projects. Fragmented adaptation finance hampers mainstreaming and scaling up in planning and development processes, increases transaction costs for recipients and donors, and diverts the time and attention of politicians and government officials away from domestic priorities to manage aid-related activities. The tens of billions of dollars required for adaptation may put additional pressure on developing countries' already limited absorptive capacity. Many of the developing countries most in need of adaptation support are those with weaker capacity to manage and absorb funding. When a recipient's capacity to manage funds is limited, donors engage in tighter controls of funds and project-based modalities, putting further strains on country systems and leading to vicious cycles of lower capacities, fiscal shortfalls, and fragmentation.[55]

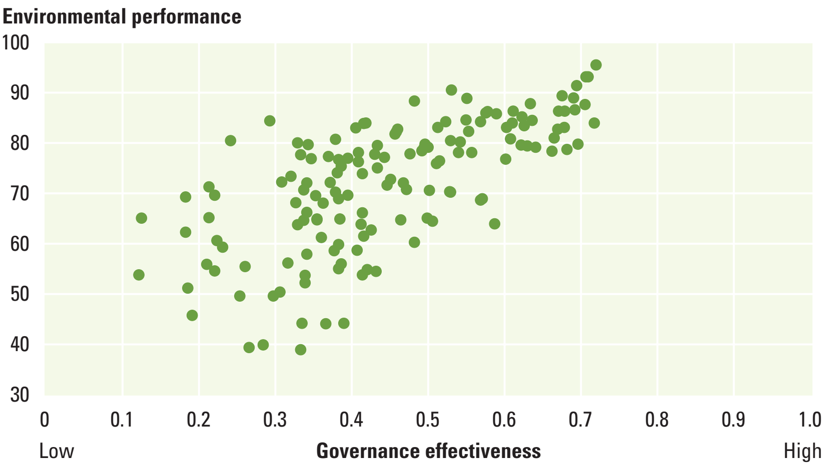
Enhancing the capacity of central government

When political leaders take an active interest, focusing the minds of officials, public opinion, and external stakeholders, countries move forward. Conversely, when leaders fail to act, countries lag behind. This is hardly surprising. Decision makers are individuals, and the failures in the way individuals make decisions also affect the way organizations, including governments, work.[56] However, leadership is not just an individual issue; it is also institutional and has to do with the way responsibility, coordination, and accountability for climate policy are organized (figure 8.6).

Assigning responsibility for climate policy. In most countries climate change is still the preserve of the environment ministry. But climate policy spills over into domains that transcend the boundaries of environmental protection and include trade, energy, transport, and fiscal policy. Environment agencies are normally weaker than departments such as treasury, commerce, or economic development. They tend to have fewer resources and to be represented in cabinets by junior politicians.

Although there is no single recipe for assigning the climate remit, reconsolidating responsibility is key (box 8.7). Bureaucratic consolidation—based on budgetary independence, expert personnel, and the authority to propose and enforce legislation—concentrates authority and avoids diffusion of responsibility that can lead to failures to act. The creation of ministerial-level agencies led by senior cabinet ministers, or the inclusion of climate policy on the agenda of already-established key

Figure 8.6 Effective governance goes hand in hand with good environmental performance



Sources: Kaufman, Kraay, and Mastruzzi 2007; Esty and others 2008.

Note: Environmental performance is measured by an environmental performance index (http://epi.yale.edu/). Governance effectiveness ranges between 0 and 1 and is derived using log transformation of the governance effectiveness indicator from the World Governance Indicators database for 212 countries for 1996–2007. It combines the views of a large number of enterprise, citizen, and expert survey respondents in high-income and developing countries.

agencies are signs of a trend toward bureaucratic consolidation.

Facilitating integration and interagency coordination. Bureaucratic consolidation, though important, may not be enough. And the mere creation of a separate agency might even be counterproductive. Policy coherence throughout an administration requires integrating climate planning across government. Here, the challenge is the typical compartmentalization of government work and the tendency to treat multidimensional problems in organizational silos. Approaches for integration include establishing climate units in each ministry or agency complemented by sectoral plans at national and local levels for mitigation and adaptation. In addition to a revision of their mandates, relevant public agencies—such as those involved in public health, energy, forestry and land-use planning, and natural resource management—can coordinate their work under a lead climate-change agency. Achieving this type of coordination is likely to require rethinking the role of hydrometeorological services (see chapter 7).

New coordination bodies—a cabinet committee on climate change, one explicitly linking climate with an already recognized and critical issue area such as energy, or an intragovernmental coordinating committee chaired by the lead agency—can bring together officials working on climate change across government. Coordination of climate policy can also be the prime minister's remit—say, by creating an advisory function directly within the prime minister's office.

For both integration and coordination, particular attention should go to developing sector policies and strategies. As chapter 4 shows, energy policy in many countries emphasizes market reform and pricing, introducing competition to the energy sector, and developing regulatory institutions to deliver low prices and reliable supplies to consumers.[57] Until very recently, mitigation was not even a tangential preoccupation of energy policy. As climate change moves up the political agenda, the mandates of energy agencies and the policies and strategies guiding them will be updated to include low-carbon supply and energy-efficiency as core responsibilities.

Strategy documents can increase the coordination of adaptation activities. Consider the National Adaptation Programs of Action (NAPAs) of least developed countries. Born as a technical priority-setting exercise, NAPAs determine country-specific impacts and design locally tailored responses by engaging different agencies and levels of government as well as broad constituencies of business and civil society actors. In this sense, they can provide an institutional framework for placing adaptation at the center of government's priorities. But to consolidate their strategic function, they will require more attention from internal and external stakeholders (box 8.8).

Reinforcing government accountability. Governments can fail to act on specific policy issues when accountability lines are not clear, either because of the nature of the

BOX 8.7 *China's and India's path to institutional reform for climate action*

China shows how responsibility for climate policy has moved from the fringes to the core of government activity. The government initially set up special institutions to address climate change in 1990. Recognizing the relevance and intersectoral nature of the issue, it established a National Coordination Committee on Climate Change in 1998.

In 2007 the committee was transformed into the National Leading Group to Address Climate Change. Headed by the Chinese premier, the leading group coordinates strategies, policies, and measures among 28 member units within government agencies. During the 2008 government reform, the general office of the leading group was placed within the National Development and Reform Commission, which undertakes the general work on climate change, supported by an expert committee providing scientific information to inform decision making.

India is another developing-country example. Its Council on Climate Change is chaired by the Prime Minister. It developed the National Action Plan on Climate Change and is responsible for monitoring its implementation. The Plan encompasses eight National Missions that span sectoral ministries since they include Solar Energy, Enhanced Energy Efficiency, Sustainable Habitat, Conserving Water, Sustaining the Himalayan Ecosystem, the creation of a "Green India," Sustainable Agriculture, and the establishment of a Strategic Knowledge Platform for Climate Change. The vision of the National Action Plan is a graduated shift from fossil fuels to non-fossil fuels and renewable sources of energy.

Similar institutional reform measures have already been adopted by a range of other countries, developed and developing.

Source: WDR team.

BOX 8.8 *National adaptation programs of action*

National Adaptation Programs of Action (NAPAs), the most prominent national efforts by the least developed countries to identify priority areas for adapting to climate change, have been subjected to three criticisms. First, the NAPA process puts in place similar projects across different countries, without paying attention to their specific adaptation needs. Second, many adaptation projects are difficult to distinguish from standard development projects. Third, the NAPA process fails to involve the major ministries and decision makers in the country or to pay enough attention to subnational and local institutional requirements.

In light of these criticisms, the World Development Report team sponsored two meetings of high-level NAPA officials in Asian and African countries, one in Bangkok in October 2008 and one in Johannesburg in November 2008. The meetings showed a more complicated picture and suggested that some criticisms may be misplaced.

Although adaptation needs and projects may appear similar when viewed collectively, they vary substantially across countries depending on the climate hazards and threats identified as most relevant. The standard NAPA guidelines explain some of the similarities in the language used to defend the identified projects as the most urgent adaptation needs. The preponderance of agricultural, natural resource, and disaster management projects reflects the fact that the impacts of climate change will be felt first in sectors related to primary goods and disaster management. Finally, the NAPAs were prepared on a shoestring, so the planning could not extend beyond the national level or across multiple ministries and decision makers.

But there is another side to the criticisms—the way the least developed countries view the NAPAs that they have prepared.

Little financial support: The total cost of all projects identified as urgent in 38 NAPA documents is less than $2 billion. Despite this low price tag, little financial support has been available, raising valid concerns about donor assistance and widening the trust gap.

Poor architecture: Institutional arrangements for adaptation need to be more permanent and better linked to different ministries with support from ministries of finance and planning and stronger connections to provinces and districts. A dedicated body can do the planning, but implementation will have to be undertaken through existing institutional and governmental structures because many projects are sectoral.

Low capacity: Capacity for adaptation planning and implementation continues to be very low in most of the least developed countries. Improvements are needed in technical capacity, knowledge, training, equipment, and modeling; some capacity in these areas could be gained from experts in universities and civil society.

Source: WDR team.

issue or because of institutional flaws. Take responses to natural disaster. Unless a country is regularly hit by severe weather events, disaster avoidance and response usually fall through the cracks of the government agenda. Leaders find it unlikely they will be scrutinized, rewarded, or sanctioned for actions that the public did not even know their governments were supposed to take (avoiding disasters). If the relationship between efforts and outcomes is not clear to the public, governments lack clear incentives for action.

Government accountability for climate policy can be enhanced by making line agencies more accountable to core government ministries, such as the treasury or the prime minister—and by making the entire government more accountable to parliament, the public, and autonomous bodies (box 8.9). Parliaments can conduct hearings, monitor performance, educate the public, and require government to engage in regular reporting on climate objectives, policy, and achievements. Inscribing climate policy targets and objectives into law can be a potent tool for greater government accountability—and to ensure continuity of action beyond a government's short time frame. An independent expert advisory body can make recommendations to government and report to parliament.

Leveraging local government action

Local and regional governments can provide political and administrative space closer to the sources of emissions and the impacts of climate change. Charged with implementing and articulating national policies, they have policy-making, regulatory, and planning functions in sectors key to mitigation (transportation, construction, public service provision, local advocacy) and adaptation (social protection, disaster risk reduction, natural resource management). Closer to citizens, subnational governments can raise public awareness and mobilize nonstate actors. And because they are at the intersection of government and the public, they become the space where government accountability for appropriate responses plays out.[58]

Probably for these reasons, local authorities often precede national governments in taking climate action. As chapter 2 shows, the regional and local levels are often more appropriate for the design and implementation of adaptation measures in agriculture, infrastructure planning, training, and water management. But local governments can also lead in mitigation. States on both U.S. coasts have developed locally owned strategies and targets and then coalesced to pilot regional carbon markets (box 8.10). Cities worldwide have their own climate action plans and strategies, adopting Kyoto targets to compensate for the inaction of national governments and becoming active members of national and transnational city initiatives, such as the C40 network of the world's largest cities committed to tackling climate change.

The relevance of local governments requires their inclusion in climate policy. Decentralizing climate policy has pros and cons, and its optimal level and scope are context specific.[59] Local governments suffer from the same limitations as central governments, though usually more severely. The climate policy remit at the local level is usually with an environment unit, with integration and coordination problems. Subnational governments usually face resource and skill gaps and have less fiscal power, which prevents them from using environmental taxes. Despite their proximity to citizens, local governments often lack the same legitimacy as national governments, because of low turnouts in local elections and weak electoral mandates or weak capacities to deliver. All this makes devolution of climate policy particularly tricky.

To enhance vertical collaboration, national governments can engage in enabling, provision, and authority measures. Enabling measures include transferring knowledge and best practice. Of interest are benchmarking initiatives linked to competition and awards for the best-performing local authorities—the provincial competitiveness index in Vietnam is a good example of such subnational benchmarking. Provision measures include performance-based public sector agreements that link funding not only to the number of inhabitants and geographical coverage of the authority but also to the achievement of targets. Authority measures include national laws requiring local governments to develop strategic plans in relevant sectors or regulation schemes to make local government officials accountable to central government, as with land-use planning.

BOX 8.9 *Enhancing government accountability for climate change in the United Kingdom*

By restructuring and establishing the institutional machinery for climate action, the United Kingdom has also deployed measures that increase the government's accountability for delivering results. The United Kingdom

- Passed a climate change bill that provided a statutory foundation for the official UK CO_2 emissions targets in the short, medium, and long terms, through five-year carbon budgets that set annual levels for permissible emissions. Three budgets spanning 15 years will be active at any given time, presenting a medium-term perspective for the evolution of carbon emissions throughout the economy.
- Designated a lead agency for climate change—the Department of Energy and Climate Change.
- Formalized in Public Sector Agreement 27 the accountability of the Department of Energy and Climate Change to the Treasury for various policy objectives and set delivery targets to measure performance in implementing them. The targets include specific steps to reduce the total U.K. emissions, increase the sustainable withdrawal of water, reduce the CO_2 intensity of the U.K. economy.
- Established a committee on climate change as an independent expert advisory body that can recommend to government ways to achieve targets. The committee reports annually to Parliament, and government is required to reply formally. Every five years the committee will offer a comprehensive assessment of the country's overall progress toward the long-term targets.

Source: WDR team.

Thinking politically about climate policy

Shaping the design and outcomes of any public policy are the strength, density, and extent of civil society; the bureaucratic culture and budget laws; and the factors driving the articulation and organization of political interests.[60] Fossil fuels, in addition to powering the economies of developed and developing countries, feed some of the special interests driving their politics. In many developing countries, carbon is not only unpriced, it is subsidized (see chapter 4). At the end of 2007 roughly a fifth of countries were subsidizing gasoline, and

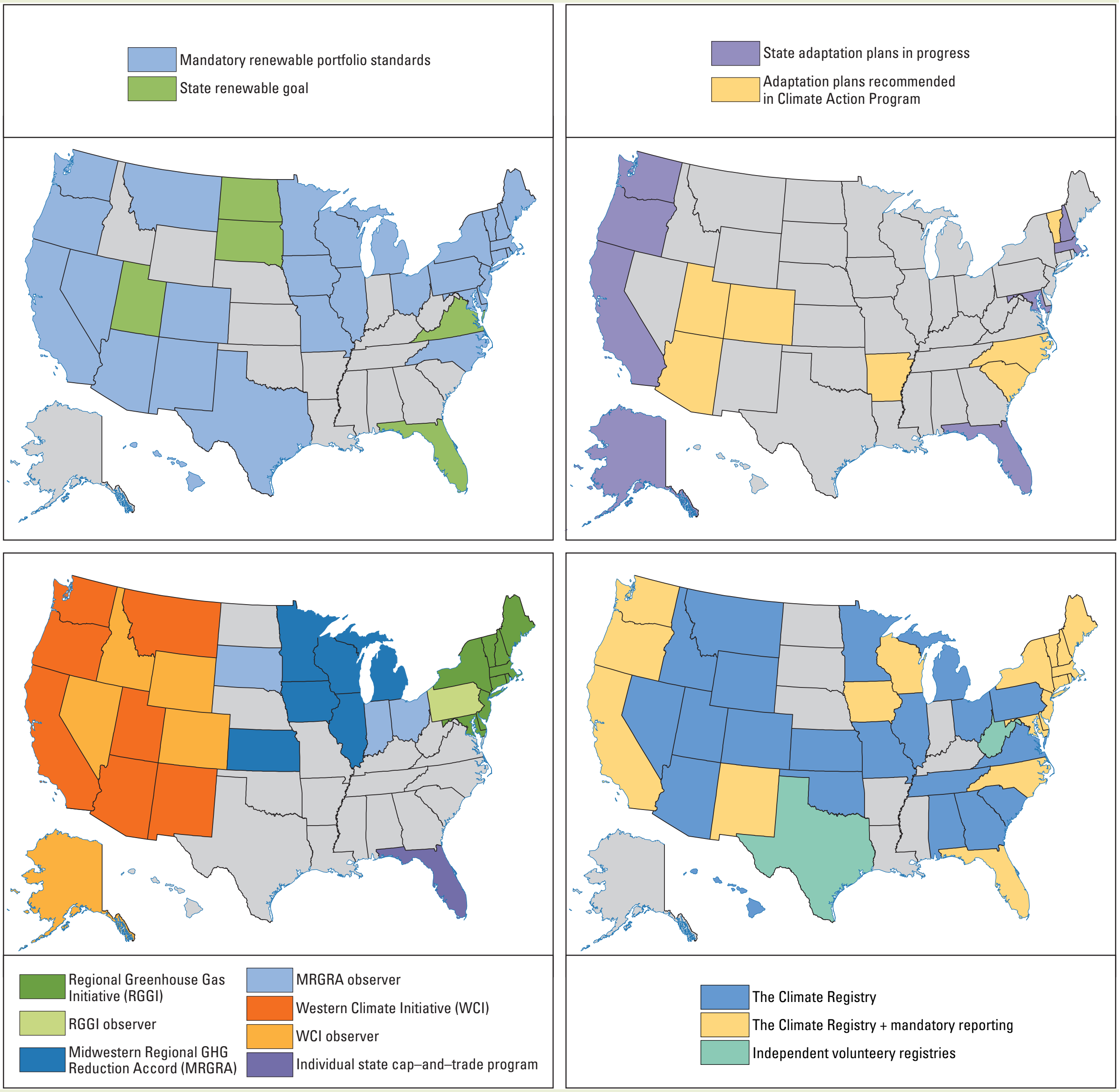
BOX 8.10 *Green federalism and climate change policy*

Subnational jurisdictions in federalist systems have long been recognized as laboratories of policy experimentation and reform.[a] State, provincial, and local governments have had varying degrees of success when it comes to efficiency and effectiveness of "green federalism" policies—those environmental policies where subnational governments take the lead.[b]

Arguments supporting green federalism include the ability of lower-level governments to tailor policies to their unique resources and demographics, as well as the opportunity to drive slower-moving national policy with innovative subnational experimentation and learning.[c] Critics of green federalism cite risks of carbon leakage, as well as the incentive for businesses to relocate in less restrictive jurisdictions. This process is often termed the race to the bottom, since it reduces environmental quality and underprovides public goods and services.[d]

But for climate policy, green federalism has shown promising results. One of the most visible examples is the United States (box map). Despite the national government's decision not to ratify the

Green federalism in the United States: State and regional action



(*continues*)

BOX 8.10 *continued*

Kyoto Protocol, and in the absence of overarching federal climate-change policy, subnational governments have taken the lead.[e] Many regions have greenhouse gas monitoring and registering programs as well as emissions reduction goals. And dozens of individual states have crafted and implemented mitigation and adaptation plans or instituted renewable portfolio standards and reduction targets. Cities and municipalities have also initiated comprehensive climate change auditing and planning programs, setting emissions reduction goals of their own.

These actions add up to significant reductions, and some claim that such efforts have led to a race to the top.[f] If the handful of states with firm emissions targets achieve their 2020 goals, U.S. national emissions could be stabilized at 2010 levels by 2020.[g]

Source: State actions are tracked by the Pew Center on Global Climate Change (www.pewclimate.org).

a. Osborne 1988.

b. Oats and Portney 2003.

c. Lutsey and Sperling 2008.

d. Kunce and Shogren 2005.

e. Rabe 2002.

f. Rabe 2006.

g. Lutsey and Sperling 2008.

slightly more than a third were subsidizing diesel fuel. More than two-thirds of low- and lower-middle-income countries were subsidizing kerosene.[61] Clearly, countries with large fossil-based energy sectors or highly energy-intensive economies face major resistance to change.[62] The result is that worldwide the sources and drivers of carbon emissions are often tied to governments' political legitimacy.

Each political system presents advantages and obstacles in addressing climate change. Take democracy. Strong evidence shows that democracies outperform autocracies in environmental policy.[63] Political freedoms improve environmental performance, particularly in poorer nations.[64] Greater civil liberties are linked with better air and water quality, such as reduced sulfur dioxide and particulates in air and lower coliform and dissolved oxygen levels in water.[65] Democracies are more likely to join international environmental regimes and treaties, are generally faster at ratifying them, and have a track record of solving global commons problems such as ozone depletion.[66]

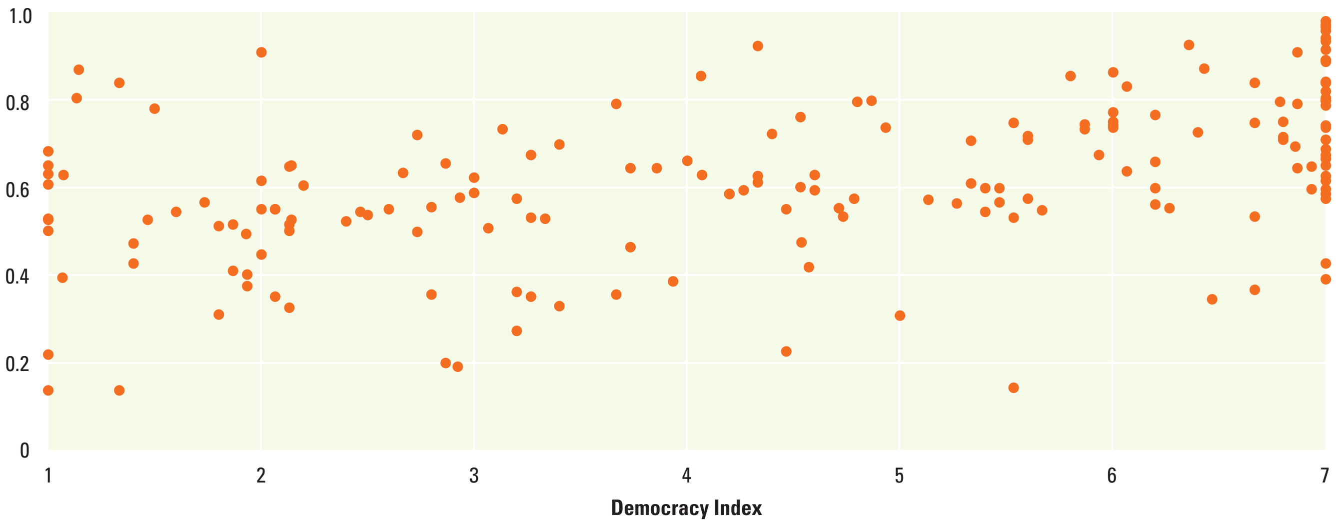
Yet democracies sometimes do better in policy outputs (signing up to international commitments) than policy outcomes (actual emission reductions), as with Kyoto.[67] As with individual consumers and voters, democracies prove more responsive in committing to solving a problem than in actually solving it, with the "green gap" in consumer attitudes translating into a words-deeds gap in government behavior (figure 8.7).[68] There are several reasons for this. Despite rising public concern about climate change, politicians keep fearing the electorate, assuming that voters are likely to be less supportive of climate action once policies affect them personally through direct and visible personal costs (carbon and energy taxes, price increases, job losses).[69] This might explain why it is harder to achieve emissions reductions through restrictions that affect individual choices. Intervening in personal mobility choices is politically tougher than targeting power plants.[70]

In political terms, climate action faces a "proximity limit." People's tendency to first address visible and direct concerns translates into a political bias favoring the solution of local environmental problems (sanitation infrastructure, water and air quality, risks associated with toxic releases, and local habitat protection) over transboundary issues (such as biodiversity loss, overfishing, or climate change).[71] The proximity limit has a temporal dimension too. Problems with long time horizons, particularly those involving public goods, are tricky to resolve. Climate change is no exception.[72] Intergenerational problems require long-term policy frameworks at odds with government time frames and electoral cycles.

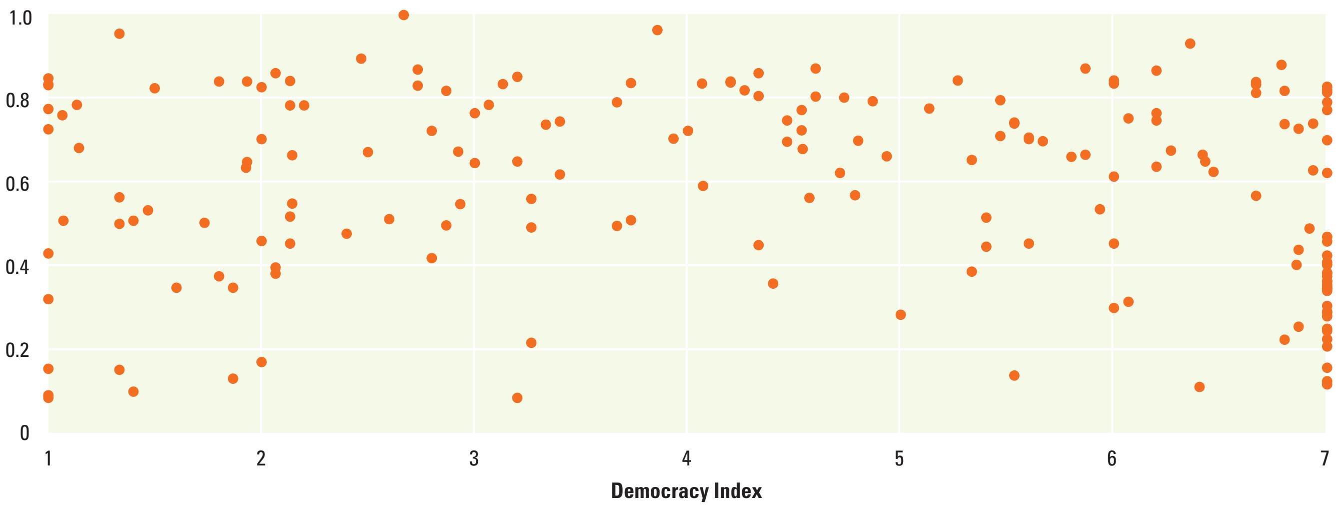
When policy issues are left without a public to champion them, shortsightedness can produce perverse incentives. Disaster risk management is an example of how standard adaptation measures can fail because the public (the voter) often fails to think in preventive terms. So decision makers neglect prevention and preparedness because these issues do not win votes. In turn, decision makers' realization that

Figure 8.7 Democracies do better in climate policy outputs than policy outcomes

Output: policies, laws, and international agreements



Output: emissions reductions



Source: Bättig and Bernauer 2009.

Note: Output is an index of cooperative behavior in climate change policy, spanning ratification of agreements, reporting, and financing—it ranges between 0 and 1, with higher values indicating more cooperation. Outcome is an index of cooperative behavior in climate change policy, spanning emission trends and emission levels—it ranges between 0 and 1, with higher values indicating more cooperation. The Political Rights Index by Freedom House is a measure of democracy encompassing the degree of freedom in the electoral process, political pluralism and participation, and functioning of government. Numerically, Freedom House rates political rights on a scale of 1 to 7, with 1 representing the most free and 7 representing the least free. However, in this figure the scale of original data has been inverted and higher values indicate a higher level of democracy. Data are 1990–2005 averages. The figure shows that there is a positive relationship between output and level of democracy, as represented by the Freedom House political rights index; democratic countries have, in general, better output. Conversely no significant relationship has been found between level of democracy and climate outcomes in the form of emission reductions (using emissions reductions in 2003 compared to 1990 levels).

disaster relief has higher political payoffs than preparedness closes the circle of moral hazard. This is far from purely theoretical. If the costs of disasters have increased dramatically, it is partly because governments realize that providing compensation to groups and areas struck by severe weather events provides major electoral benefits.[73] This realization works against policy change and reinforces bad policies. Government crop insurance reduces farmers' incentives to avoid weather damage. Disaster relief leads citizens and local governments to expect compensation as an entitlement rather than take preventive measures.[74]

Climate reforms depend on political support. Any policy change generally meets resistance, particularly when it involves visible costs to large and diverse actors. Climate policy is a perfect example, because its costs are going to be clearly visible to various economic groups and the population at large. Building public support for climate policy can take many avenues.

Devise interventions that a maximum number of (key) political actors can agree on

Design policies that yield co-benefits. Countries abiding by and implementing international environmental obligations tend do so because of local incentives: air pollution, water quality degradation, direct and visible environmental threats.[75] Individuals contribute to public goods more easily when they see a direct benefit. Actively seeking overlapping goals and benefits should be a core part of a politically sustainable climate policy.[76] Not all climate-smart development policies are climate specific, and a range of actions can overcome the (perceived) tradeoffs between economic development and climate action. The challenge is to frame climate action in terms of local, private, and near-term goals and co-benefits—such as energy security, energy efficiency, public health, pollution abatement, and disaster risk reduction.

Target key constituencies. The co-benefits of climate policy can win over opposing vested interests. Take labor. Where the short-term employment effect of climate policy is negative, offsetting payoffs for organized labor should be made clear. Unions can be brought round by demonstrating to them how a low-carbon economy is more labor intensive than a conventional one; how energy savings can be turned into higher, labor-intensive expenditures; how investments in technology development and deployment will create jobs; and how the revenues from energy taxes can offset taxes on labor, increasing the demand for workers. It is important to carefully assess whether policies are perceived to be unduly favorable to one key group or the other. Support for climate policy is strong among groups that see a low-carbon economy as a business opportunity, but legacy industries remain opposed. Grandfathering emission permits is often cited as a strategic measure to get the longer-term buy-in of business, but the scheme also generates public resistance (box 8.11).

Rely on consensus processes and instruments. Obtaining the prior agreement of the main stakeholders on specific measures can reduce political damage. In addition to identifying co-benefits, consensus policies involve setting up consultative systems and voluntary schemes that bind key actors such as industry groups to the principles of climate policy. Consultative political systems seem to be more effective in environmental policy.[77]

Increase the public's acceptance of reforms

Pursue equity, fairness, and inclusion. A decision maker's aversion to inequity is a product of both ethics and politics, because redistributional outcomes normally lead to political payoffs or sanctions by voters. The public is more likely to accept policy change if it is seen as tackling a severe problem and if its costs and benefits are perceived as equitably distributed. This calls for designing progressive and equitable climate policies involving transparent compensatory measures for the poorest. Green fiscal policies can be progressive and play a strong equity role.[78] Revenue recycling from carbon taxes or auctioned permits can support tax cuts and provide economic stimulus. Earmarking the proceeds of carbon permits and taxes for social protection schemes can increase

BOX 8.11 *Garnering support for cap-and-trade*

The European Union recently created an emissions trading system to meet its Kyoto obligations. Overall, the system has many good features. One peculiarity is that EU countries are required to grandfather credits (give them freely) to firms despite the potentially huge rents associated with them and the clear economic gains to be had from auctioning credits. In part because of this grandfathering rule and the implicit recognition of the large rents associated with it, the allocation mechanism is set only for five-year periods.

These short allocation periods avoid giving away too much wealth through rent creation and capture. But the massive windfalls for major polluters drew media attention and alienated the public. The five-year system also created perverse incentives for strategic behavior to influence the next allocation rule and was protested by firms aiming to enter the industry.

Source: WDR team.

the acceptance of energy-pricing reforms. In several European countries revenues raised from charges on air pollutants, hazardous wastes, and toxic chemicals reduce income taxes and social security contributions.

Lead by example. Policy makers can set social norms by changing the behavior of government. The greening of government can play an important communication role in addition to providing immediate benefits in reducing emissions and catalyzing research and investments in new technologies. Where feasible, government can also revise instruments such as public procurement to support green objectives.

Use weather-related natural disasters as teaching moments. Disasters can provide "focusing events" that lead to rapid policy change, although the window of opportunity is usually short.[79] The 2003 heat wave in Europe, Hurricane Katrina in 2005, and Australia's 2009 wildfires all increased attention to climate change. Such events can provide an opening for government to take actions unpopular in normal times.[80] Postdisaster reconstruction also provides opportunities to depart from past practices and build more resilient communities and societies.

Increase the acceptability of policies. Swift and sudden government actions can circumvent groups that want to maintain the status quo and create a feeling of inevitability, if momentum is maintained.[81] But gradualism can also increase the acceptability of policies, because incremental policy changes usually draw less attention and resistance. This could explain why major economies have been slow in starting to reduce emissions. Small, incremental changes can establish platforms for advancing larger changes later on. Here, establishing predictability—setting the long-term orientation of government policy—allows stakeholders (in and outside government) to identify the incentives they need to reorient their activities.[82]

Improve communication. Well-designed communication strategies not only can help change behaviors—they can also mobilize political support for reform. Public information campaigns have been key to successful subsidy reforms, even where groups capturing the subsidies were better organized and more powerful than the beneficiaries of reform (consumers and taxpayers). Communication should focus on filling the knowledge gap and addressing what can be rationally based opposition to reforms. For instance, demystifying some of the unsubstantiated perceptions of the negative sides of climate policies can reduce uncertainty and opposition. Research shows that fears of racing to the bottom and losing competitiveness are exaggerated and that investing in new green technology can lead to the development of markets for environmental goods and services.[83] Similarly, stressing that environmental taxes are not simply a source of revenue for the state but a key to changing behavior is central to enhancing public acceptability.

Address structural deficiencies of political systems

Reinforce political pluralism. Vested interests, including those that fear climate policies would harm their business or industry, may have a stake in limiting the scope and impact of climate policy. Measures to reduce interest group activity aimed at capturing or hijacking climate policy include reinforcing political pluralism. This can have varying impacts on policy change. A large number of veto players can produce a policy gridlock.[84] But political pluralism generally reduces behind-closed-door lobbying and corruption by giving access and voice to countervailing interests.[85] Environmental interests have overwhelmed business interests trying to curtail the stringency of environmental policies in food safety, renewable portfolio standards, and waste regulation.[86] Political pluralism can also foster coalitions of environmental and business interests as drivers of change.

Promote transparency. Clarifying the cost of energy and its components (production, imports, distribution subsidies, and taxes) can build support for reform of energy markets. In mitigation policy one major advantage of transparent reporting of the cost of energy is that the additional cost of carbon is

BOX 8.12 *The private sector is changing practices even without national legislation*

Private sector actors have stepped up their actions to reduce greenhouse gas emissions, even in countries lacking comprehensive climate-change legislation. An increasing number of firms have developed voluntary emissions targets and reporting standards. In 2008 a record 57 climate-related shareholder resolutions were filed in U.S. boardrooms—double the number five years earlier. Support for these measures averaged more than 23 percent among shareholders—another all-time high.

Carbon-intensive firms have also come together to discuss strategy for mitigating climate change. In early 2009 the U.S. Climate Action Partnership, an alliance of more than two dozen major greenhouse-gas-emitting companies and several nongovernmental organizations, put forth a unified plan for federal legislative action that calls for an 80 percent reduction of 2005 emission levels by 2050. The Business Roundtable, an association of leading U.S. companies, has mapped ways to improve conservation, efficiency, and domestic energy production between now and 2025. The Prince of Wales International Business Leaders Forum, an independent organization that supports more than 100 of the world's leading businesses, launched the Business and the Environment program in recognition of the impact of climate change on business operations and liabilities.

This drive is pushing entire industries to shift their practices. In March 2009 the U.S. insurance association implemented a first-of-its-kind requirement that all insurers must evaluate the climate-change risks posed to the companies they insure and disclose their plans for managing such risks. These include direct risks posed by climate-change impacts and indirect risks posed by policy initiatives to mitigate climate change. Similarly, the financial investment industry is moving to increase the disclosure of climate risks in publicly traded companies, while promoting climate-smart investments.

Source: WDR team.

put in relative terms. Transparency has been particularly useful in raising public awareness about the costs of energy subsidies, assessing the tradeoffs, and identifying winners and losers. Some countries have subsidy reporting systems to enhance public understanding of their costs and benefits.[87]

Make it difficult to reverse policy. Political and institutional arrangements can help avoid shifting action on climate change from the living to the unborn by making it difficult to reverse climate policy. Such arrangements could include constitutional amendments and climate-change laws.[88] But they can also involve the establishment of independent institutions that take a longer-term view, in the same way that monetary institutions control inflation.

Climate-smart development starts at home

The quest for appropriate responses to climate change has long focused on the need for an international agreement—a global deal. Although important, a global deal is only a part of the answer. Climate change is certainly a global market failure, but one articulated according to locally defined causes and effects and mediated by context-specific circumstances.

This means that climate policy—for both mitigation and adaptation—has local determinants. A study on the adoption of renewable portfolio standards across U.S. states shows that political liberalism, renewable energy potential, and concentrations of local air pollutants all increase the probability that a state will adopt such standards. On the other hand, carbon intensity tends to decrease this probability.[89] International regimes influence domestic policies, but the reverse also holds. A country's behavior in shaping, adhering to, and implementing a climate deal depends on domestic incentives. Political norms, institutional structures, and vested interests influence the translation of international norms into domestic political dialogue and policy, while shaping the international regime by driving the national actions.[90] A country's wealth, its energy mix, and its economic preferences—such as the propensity for state-driven or market-driven responses—will shape mitigation policy. Cultural and political traditions are added to economic and administrative considerations in choosing taxes or cap-and-trade. And because of the lack of an international sanctioning mechanism, the incentives for meeting global commitments need to be found domestically, through concentrated local benefits such as cleaner air, technology transfer, and energy security.

Climate action is already taking place. Countries have shown different levels of commitment and performance in reducing emissions. Small countries—which in theory should have incentives to free ride, given their negligible role in global emission reductions—have so far undertaken more aggressive actions than the big players. In some countries subnational measures and homegrown policy responses are already affecting national policy and the position of countries in the international arena. And the private sector is showing that old practices can give way to new visions (box 8.12).

Reversing the institutional inertia that constrains climate policy requires fundamental changes in interpreting information and making decisions. A range of actions can be taken domestically by national and subnational governments as well as by the private sector, the media, and the scientific community. Although establishing an effective international climate regime is a justified preoccupation, it should not lead to a wait-and-see attitude, which can only add to the inertia and constrain the response.

Notes

1. North 1990.
2. Soderholm 2001.
3. Sehring 2006.
4. Foa 2009.
5. Gardner and Stern 2008.
6. Gardner and Stern 2008.
7. Bannon and others 2007; Leiserowitz 2007; Brechin 2008; Sternman and Sweeney 2007.
8. IPPR 2008; Retallack, Lawrence, and Lockwood 2007.
9. Wimberly 2008; Accenture 2009.
10. Norgaard 2006; Jacques, Dunlap, and Freeman 2008.
11. Bulkeley 2000.
12. Kellstedt, Zahran, and Vedlitz 2008.
13. Immerwahr 1999.
14. Krosnick and others 2006.
15. Boykoff and Mansfield 2008.
16. Oreskes 2004; Krosnick 2008.
17. Miller 2008.
18. Bostrom and others 1994.
19. Bazerman 2006.
20. Sternman and Sweeney 2007.
21. Ornstein and Ehrlich 2000; Weber 2006.
22. Repetto 2008.
23. Moser and Dilling 2007; Nisbet and Myers 2007.
24. Maslow 1970.
25. Olson 1965; Hardin 1968; Ostrom 2009.
26. Irwin 2008.
27. Winter and Koger 2004.
28. Sandvik 2008.
29. O'Connor and others 2002; Kellstedt, Zahran, and Vedlitz 2008; Norgaard 2006; Moser and Dilling 2007; Dunlap 1998.
30. Norgaard 2009.
31. Ward 2008.
32. Krosnick 2008.
33. Kallbekken, Kroll, and Cherry 2008.
34. Swallow and others 2007.
35. Clifford Chance 2007.
36. Romm and Ervin 1996.
37. Roland-Holst 2008.
38. Laitner and Finman 2000.
39. Cialdini and Goldstein 2004; Griskevicius 2007.
40. A. Corner, "Barack Obama's Hopes of Change Are All in the Mind." *The Guardian*, November 27, 2008.
41. Irwin 2008.
42. Irwin 2008.
43. Layard 2005.
44. Sterner 2003.
45. World Bank 1992; World Bank 1997; World Bank 2002.
46. Wade 1990.

"Ever think of emigration outside the world? To the Moon, Mars, or Venus? But our Earth is known to be the most beautiful planet of all. I still want to live in this wonderful place—with birds singing everywhere, the aroma of flowers in the air, green mountains, and blue icebergs. So everybody, please start to work together to conserve the beauty of Mother Earth. Join me now in making the world better."

—Giselle Lau Ching Yue, China, age 9

47. Stern 2006.
48. Haites 2008.
49. Janicke 2001.
50. Giddens 2008.
51. Bernauer and Koubi 2006.
52. Meadowcroft 2009.
53. Birkland 2006.
54. Bazerman 2006.
55. OECD 2003.
56. Bazerman 2006.
57. Doern and Gattinger 2003.
58. Alber and Kern 2008.
59. Estache 2008.
60. Kunkel, Jacob, and Busch 2006.
61. IMF 2008.
62. Kunkel, Jacob, and Busch 2006.
63. Congleton 1992; Congleton 1996.
64. Barrett and Graddy 2000.
65. Torras and Boyce 1998.
66. Congleton 2001; Schneider, Leifeld, and Malang 2008.
67. Rowell 1996; Vaughn-Switzer 1997.
68. Bättig and Bernauer 2009.
69. Compston and Bailey 2008.
70. Bättig and Bernauer 2009.
71. Bättig and Bernauer 2009.
72. Sprinz 2008.
73. Schmidtlein, Finch, and Cutter 2008; Garrett and Sobel 2002.
74. Birkland 2006.
75. Dolsak 2001.
76. Agrawala and Fankhauser 2008.
77. Compston and Bailey 2008.
78. Ekins and Dresner 2004.
79. Birkland 2006.
80. Compston and Bailey 2008.
81. Kerr 2006.
82. "A Major Setback for Clean Air," *New York Times*, July 16, 2008.
83. Janicke 2001.
84. Tsebelis 2002.
85. Dolsak 2001.
86. Vogel 2005; Bernauer and Caduff 2004; Bernauer 2003.
87. IMF 2008.
88. Kydland and Prescott 1977; Sprinz 2008.
89. Matisoff 2008.
90. Davenport 2008; Kunkel, Jacob, and Busch 2006; Dolsak 2001; Cass 2005.

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