Climate Change and Development Series

DECARBONIZING DEVELOPMENT

Three Steps to a Zero-Carbon Future

OVERVIEW

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Overview

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This booklet contains the Overview as well as a list of contents from the forthcoming book, *Decarbonizing Development: Three Steps to a Zero-Carbon Future* (DOI: 10.1596/978-1-4648-0479-3). A PDF of the final, full-length book, once published, will be available at openknowledge.worldbank.org and print copies can be ordered at www.amazon.com. Please use the final version of the book for citation, reproduction and adaptation purposes.

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Climate Change and Development

The Climate Change and Development Series was created in 2015 to showcase economic and scientific research that explores the interactions between climate change, climate policies, and development. The series aims to promote debate and broaden understanding of current and emerging questions about the climate-development nexus through evidence-based analysis.

The series is sponsored by the Climate Change Vice Presidency of the World Bank, and its publications represent the highest quality of research and output in the institution on these issues. The group is committed to sharing relevant and rigorously peer-reviewed insights on the opportunities and challenges present in the climate-development nexus with policy makers, the academic community, and a wider global audience.

Contents of *Decarbonizing Development*

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Overview

Stabilizing climate change entails reducing net emissions of carbon dioxide (CO_2) to zero. This report outlines three principles to guide countries in their efforts to create a zero-carbon future: (a) planning ahead with an eye on the end goal; (b) going beyond carbon pricing with a policy package that triggers changes in investment patterns, technology, and behaviors; and (c) protecting poor people and avoiding concentrated losses. Although countries at different levels of income and with different endowments will adopt different strategies, all have a role to play.

Stabilizing climate change entails reducing net emissions of carbon dioxide (CO_2) to zero. CO_2 stays in the atmosphere for hundreds, if not thousands, of years. As long as we emit more than nature can absorb in its sinks (oceans, forests, and other vegetation), concentrations of CO_2 in the atmosphere will keep rising, and the climate will keep warming. And the decisions we make now will determine the planet's climate for centuries.

The latest science also tells us that we need to reach zero net emissions by 2100 to stabilize climate change around the 2°C target above preindustrial temperatures that has been agreed by governments as the maximum acceptable amount of warming. Relaxing the target to 3°C would make little difference in the policies needed, although a 2°C target would require more aggressive, earlier action.

But can we envisage a world in which economic activities have been made completely carbon neutral by the end of the century? Here, we should emphasize that *carbon neutrality* or *decarbonization* does not imply no emissions whatsoever. Positive emissions in some sectors and some countries can be offset, to some extent, through natural carbon sinks and negative emissions in other sectors and countries. So decarbonization means zero net emissions of CO_2—as well as the stabilization of emissions of short-lived greenhouse gases such as methane that dissipate in the atmosphere in days, weeks, or decades.

The latest report of the Intergovernmental Panel on Climate Change (IPCC)—which presents the consensus views of 830 scientists, engineers, and economists from more than 80 countries and was formally endorsed by the governments of 194 countries—identified many possible pathways to reach carbon neutrality by the end of the century. All require acting on four fronts: (a) decarbonization of electricity; (b) massive electrification (using that clean electricity) and, where that is not possible,

a switch to lower-carbon fuels; (c) greater efficiency and less waste in all sectors; and (d) improved carbon sinks (such as forests, vegetation, and soil).

In practical terms, what does this mean for countries, especially developing countries that are already struggling to reduce poverty and achieve prosperity? Many are unable to keep up with the investments to satisfy the basic needs of their citizens, let alone the efficient cities, roads, housing, schools, and health systems they aspire to create. At the same time, the fact that much of their infrastructure is yet to be built means opportunities exist to act early and gain efficiency. Thus, the pursuit of a low-carbon transition must be integrated into the overall development agenda: the goal is not just to decarbonize, but to decarbonize development.

The aim of this report is to take this lofty goal of zero emissions by 2100 and examine what it means in terms of today's policy making for development. It does not discuss whether or why to stabilize climate change, or at which level we should do so. Our starting point is the 2°C goal set by the international community. We begin by examining how planning can help lay the foundation for both a stable climate and a good development path. Next, we explore how countries can create the right enabling environment so that the needed technology, infrastructure, and financing are available. Finally, we discuss how countries can carefully manage the transition, given the vital role that the political economy will play.

The message of this report is that to decarbonize development, and to do so by 2100, three broad principles must guide countries' low-carbon efforts:

- *Plan ahead with an eye on the end goal.* The appropriate way to achieve a given reduction in emissions by, say, 2030 depends on whether that is the final target or a step along the way to zero net emissions. If the latter, early action will need to be a mix of cheap, quick fixes and costlier long-term measures to promote technology development, investment in long-lived infrastructure, and changes in how cities are built. So every country needs to define a long-term target—say for 2050—that is consistent with decarbonization and to build short-term, sector-specific plans that contribute to that target and are adapted to the country's wealth, endowments, and capacity. The good news is that many options with high potential offer immediate local co-benefits, especially in low-income countries, so that early action need not represent a trade-off with short-term development goals.
- *Go beyond prices with a policy package that triggers changes in investment patterns, technologies, and behaviors.* Carbon pricing is necessary for an efficient transition toward decarbonization. It is also an efficient way to raise revenue, which can be used to support poverty reduction and development or to reduce other taxes. And a carbon tax can be designed to be administratively simple yet harder to evade than taxes on income or capital. But carbon pricing alone cannot solve the climate change problem, given the many market failures and behavioral

biases that distort economies. Policy makers also need to adopt measures such as targeted investment subsidies, performance standards and mandates, or communication campaigns that trigger the required changes in investment patterns, behaviors, and technologies—and if carbon pricing is temporarily impossible, to use those measures as a substitute.

- *Mind the political economy and smooth the transition for those who stand to be most affected.* Reforms live or die on the basis of how well the political economy is managed: a climate policy package must be attractive to a majority of voters and avoid impacts that appear unfair or that are concentrated in a region, sector, or community. Thus, reforms have to smooth the transition for those who stand to be affected—by not only protecting vulnerable people but also avoiding concentrated losses and sometimes compensating powerful lobbies. Fortunately, getting rid of environmentally harmful subsidies and pricing carbon provide additional resources with which to improve equity, to protect those affected, and, when needed, to appease opponents.

Of course, these are broad principles that every country will need to interpret in light of its own needs, institutions, and aspirations. Even so, a few generalizations can be made. Low-income countries, given their extremely low emissions levels, should focus on options that are consistent with immediate poverty alleviation and that do not stand in the way of short-term growth, including the adaptation and diffusion of technologies developed elsewhere. Richer countries can afford to implement more expensive measures and take the lead on developing frontier technologies such as carbon capture and storage and subsidizing their deployment so that the technologies improve and their cost decreases.

But all countries should work to avoid creating carbon-intensive lock-ins that will be costly to reverse later and to capture the large economic and health co-benefits from a cleaner and more efficient economic system. Further, income is not the only factor that differentiates countries. Countries that are rapidly urbanizing have a crucial window of opportunity to create cities that are energy efficient and easy to serve with public transit. Countries with large forests can achieve a lot by focusing on reducing irreversible deforestation. More generally, countries differ by the endowment of natural resources—for instance, their potential for hydropower or solar energy—and will therefore implement very different strategies. But, although countries will follow different pathways, all countries have a role to play.

Planning for a Low-Carbon Future: What We Need to Do Now Depends on the End Goal

A key reason scientists believe it is possible to achieve full decarbonization by 2100 is that they have looked at pathways that would do so. Those pathways are derived from various energy and economic models that examine what it would take to achieve

decarbonization under a number of different scenarios of economic growth and technological innovation. As mentioned earlier, what all models and modelers agree on is that action will be needed on four fronts:

- Decarbonizing the production of electricity
- Undertaking massive electrification (to increase reliance on clean electricity) and, where not possible, switching to cleaner fuels
- Improving efficiency and reducing waste in all sectors
- Preserving and increasing natural carbon sinks through improved management of forests and other vegetation and soils

The question is when to begin and at what speed to proceed. Fortunately, there is no need for all countries to follow the same path or rhythm. Weaker efforts early on can be offset (up to a point) by greater efforts later, and more effort now means less will be needed tomorrow. And since decarbonization is a global goal, greater efforts by a richer or more able country can offset less intense efforts by a country with less capacity. As the IPCC argues, multiple pathways can lead to decarbonization. However, the key to feasibility is affordability, and affordability requires early action.

Early Action

Early action is vital for two reasons. First, it is cost-effective, because it allows countries to take advantage of natural opportunities to green their capital as it is retired or as it is first built. The alternative is delays, which imply the continued construction of dirty power plants and other capital that create "committed emissions." For example, the fossil-fueled power plants built in 2012 alone will emit some 19 billion tons of CO_2 over their expected 40-year lifetime, more than the annual emissions of all operating fossil-fueled power plants in 2012. Retiring them early is possible, but costly. The models reviewed by the IPCC find that if mitigation is postponed until 2030, costs would rise an average 50 percent for the 2030–50 period, and 40 percent for the longer term (2050–2100).

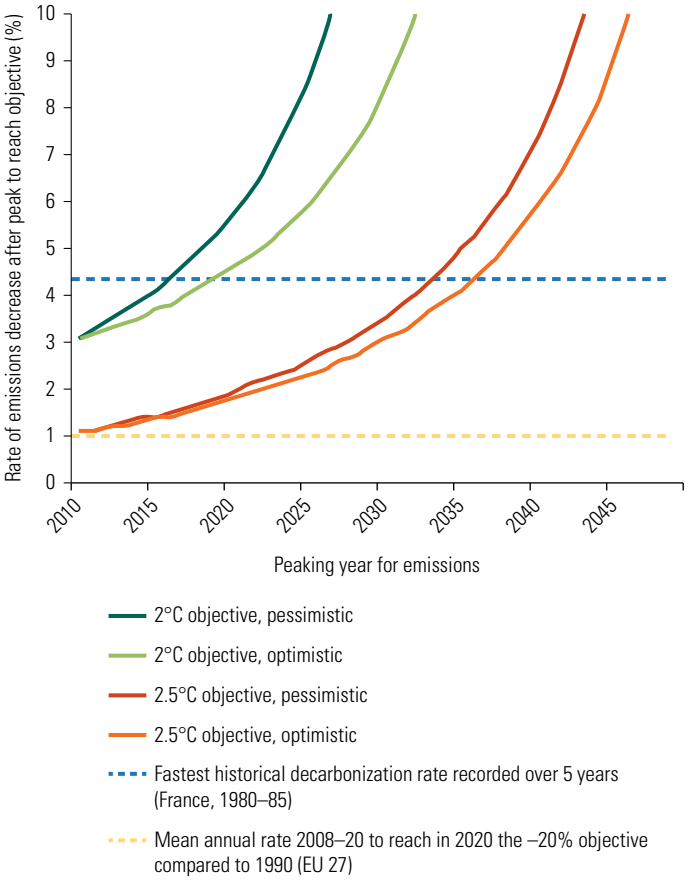
Second, early action is prudent because delays can result in lock-ins and the loss of options. A failure to invest in developing new technologies such as carbon capture and storage now may mean they are not available by midcentury when they are needed. And trying to retrofit a low-density city to make it more carbon efficient and suitable for public transit is extremely difficult, as city managers around the United States are finding out.

Thus, the pledges made by member countries of the United Nations Framework Convention on Climate Change in Cancún in 2010 are worrisome: they amount to such modest reductions in the short run that they would require annual cuts in emissions of 6 percent per year from 2030 onward to achieve the globally endorsed stated objective of 2°C. Historically, such rapid declines have occurred only during economic

collapses, such as the fall of the Soviet Union. The highest decarbonization ever achieved in a planned fashion was 4.5 percent per year, when France deployed its nuclear energy program (figure 0.1).

Some will say that waiting can also save money: as technologies evolve, they improve, become more affordable, and open up new options. But if everyone waits, those technologies will not be invented, and they certainly will neither improve nor become more affordable. And in the face of development pressures, waiting is not always an option. Things get built anyway—but incorrectly, as is occurring in much of the urbanization taking place in developing countries.

FIGURE 0.1 The Tortoise and the Hare: Not Starting Early Will Entail More Drastic Emission Cuts Later



Source: Adapted from Guivarch and Hallegatte (2013).

Note: Peak year refers to the year in which emissions have reached their highest level and start to decline. Delaying the peak year by just a few years, say from 2010 to 2020, entails increasing the rate of annual emissions reduction from 3 percent to 4.5–5.5 percent. The figure also reports the fastest historical decarbonization rate achieved over a five-year period (outside of periods of economic collapse) and the decarbonisation rate implied by the European Union's commitment between 2008 and 2020. EU = European Union.

So someone has to start. And when it comes to new technologies, the richer countries must lead in funding frontier innovation and creating the demand that allows for large-scale deployment and lower costs. Thus, the massive expansion in solar energy in Germany has been critical in reducing the cost of solar panels. But even very poor countries can identify early action that makes sense within their overall development strategy.

What exactly does early action entail? And how should policy makers make decisions in situations of uncertainty, multiple worldviews, and competing objectives? We would argue, as we did in *Inclusive Green Growth: The Pathway to Sustainable Development* (World Bank 2012), that countries should focus on actions that offer synergies with short-term development goals or that are urgent:

- *Synergies.* Many mitigation options (such as public transit, cleaner energy, and energy efficiency) offer immediate and local economic and welfare benefits. Prioritizing those options will help ensure that climate considerations are well integrated into countries' development plans and will increase political acceptability. For example, some analyses suggest that the health benefits of cleaner air alone would exceed the cost of mitigation in many regions at least until 2030 (Shindell et al. 2012; Thompson et al. 2014).
- *Urgency.* Some mitigation options are associated with high technical inertia (meaning that they carry a risk of lock-in, irreversibility, or higher costs if action is delayed)—such as unplanned low-density urban expansion or the cutting down of old-growth forests. Some abatement actions will take time and will need to be implemented early (such as research and development for the needed technologies and support for their deployment). For them, action is urgent. Otherwise, action can be postponed for measures that create hard trade-offs with other development goals in poor countries.

Planning Ahead

The good news is that a number of planning tools are available to help countries—poor and rich alike—devise an appropriate decarbonization plan. But the key is to use these tools with an eye on the end goal for a number of reasons.

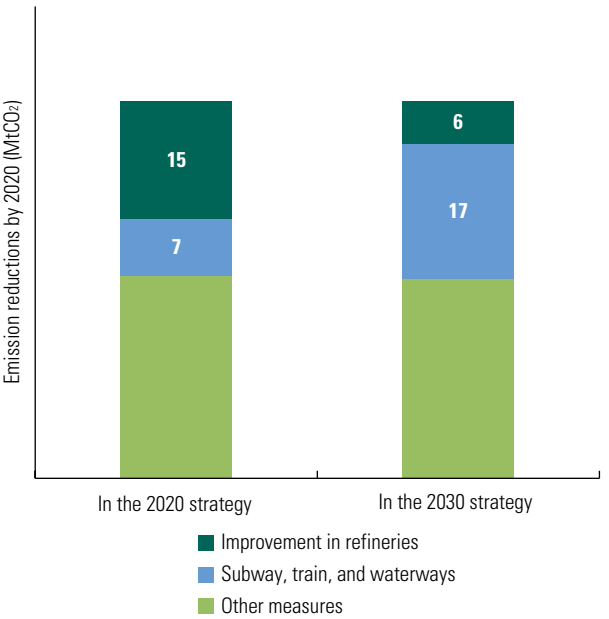
First, keeping an eye on the end goal will help poorer countries align development and poverty alleviation with climate policies. Higher emissions from better energy access or structural change in poor low-emission countries or regions should not be a concern as long as irreversible carbon lock-in is avoided (possibly by using urban plans and well-enforced building norms). Indeed, those countries should use low-cost options to maximize poverty reduction, which may include coal where solar power or hydropower is not possible or is too expensive. That said, they would still benefit from capturing the potential for low-cost renewable power (such as hydropower), avoiding energy waste, improving air quality, and creating a cost-efficient economic system (with appropriate energy pricing and performance standards).

In addition, for all countries, a focus on short-term targets (such as 2030) without considering long-term ones (such as for 2050 and beyond) would lead to emission reductions based on the cheapest options—which may lack the potential to achieve complete decarbonization. It could thus result in a carbon-intensive lock-in, making it much more expensive to achieve the long-term objective.

Take the case of a low-carbon strategy analysis done for Brazil. As figure O.2 shows, the optimal strategy for a 2020 end goal makes greater use of marginal actions that are cheap and easy to implement but that have a limited potential (improved energy efficiency in refineries). In contrast, the optimal strategy for a 2030 end goal entails more ambitious actions that are more expensive and take longer to implement but that have the potential to contribute to deeper decarbonization. Thus, if the goal is simply a 10 percent reduction in 2020, limited use should be made of investments in subways, trains, and waterways—although those investments are critical to ensure the feasibility of a 20 percent reduction by 2030.

The key to designing an emission-reduction plan that accounts for the long term is to consider three characteristics of each option: cost, mitigation potential, and time needed to implement. Options with "negative costs" (such as energy efficiency) or large development co-benefits should be implemented as soon as possible. But as figure O.3

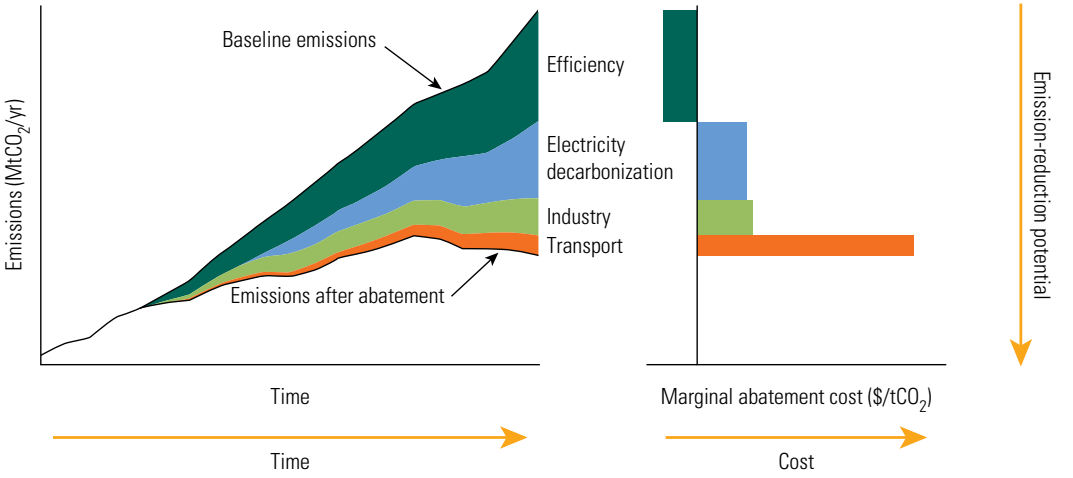
FIGURE O.2 Using a Longer Time Frame Changes the Optimal Policy Mix for Brazil



Source: Adapted from Vogt-Schilb, Hallegatte, and de Gouvello (2014).

Note: The 2020 and 2030 bars amount to an equivalent amount of emission reduction, although they include a different mix of measures; $MtCO_2$ = million tons of carbon dioxide.

FIGURE O.3 Devising a Strategy Requires Information on Time, Cost, and Emission-Reduction Potential



Note: The "wedge curve" on the left shows emission-reduction potential as well as the time it takes to roll out a particular option (such as efficiency or electricity decarbonization). It is combined with a marginal abatement cost curve that shows emission-reduction potential and their cost, so that the three key dimensions of emission-reduction options—time, cost, and potential—can be displayed simultaneously. Numbers displayed are purely illustrative. The two graphs are certainly not sufficient to develop a full strategy. More information is needed on obstacles to implementation (such as why negative costs options have not been implemented already), but they do help highlight the need for looking at the three key dimensions simultaneously.

illustrates with a fictional example, options that are expensive but that are slow to reach their full potential (such as transport) may also have to get started early in order to reach the long-term goal. In contrast, cheaper options may be delayed—in figure O.3, electrification is cheaper than transport but can be introduced later without threatening the long-term goal.

With this information, governments can design operational short-term targets to ensure that they make progress in all sectors. For instance, a target may be to produce 30 percent of electricity from renewable sources by 2030, to drive cars that emit less than 80gCO_2 per kilometer by 2025, or to use wood materials—from sustainably managed forests—instead of steel and cement in half of all new buildings by 2035. This sectoral approach has an advantage over economy-wide emission goals, because the latter could be achieved with marginal actions that do not contribute sufficiently to meeting the long-term objectives.

Enabling the Transition with a Policy Package That Is Efficient, Acceptable, and Credible

Good planning is important, but so are incentives and policies that ensure planned actions are implemented and projects are financed. Thus, carbon pricing is a critical policy, as it addresses a major market failure—the failure to price the environmental

damage caused by greenhouse gases. However, a multiplicity of market and government failures comes together to make climate change a complex problem to solve. So pricing is necessary, but not sufficient, especially if a low-carbon strategy is to be politically acceptable and credible enough to trigger the kind of long-term investments that are needed. Also needed are complementary measures to make individuals and firms more responsive to prices—or substitutes for prices when they are ineffective.

Getting Prices Right—Good Economic and Fiscal Policy

Schemes to get prices right have the great advantage of raising revenues in an economically and fiscally efficient way, making them good fiscal policies, in addition to their environmental benefits. That advantage is obvious with the elimination of environmentally harmful subsidies, but it is also the case for carbon pricing—whether taxes or cap and trade (provided that permits are sold or auctioned).

Getting prices right includes reforming fossil-fuel subsidies—which reached about $548 billion in 2013, according to the International Energy Agency, a number that is likely to be an underestimate. Even so, this sum still averages a whopping 5 percent of gross domestic product and 25–30 percent of government revenues among the 40 mostly developing countries for which it was calculated (IEA 2014). In addition, the Organisation for Economic Co-operation and Development estimates that its member countries spent $55–$90 billion a year in the 2005–11 period (OECD 2013). Other environmentally harmful subsidies, such as agricultural support schemes that incentivize the overuse of pesticides and fertilizer and excessive emissions, need to be reformed as well.

Encouragingly, good progress has been made in recent years. Over the past two years, more than 25 countries, many in Asia, have significantly reformed their fossil-fuel subsidies. Indonesia abandoned a four-decades-old policy of subsidizing gasoline, India liberalized diesel prices and raised fuel taxes, and Malaysia eliminated subsidies on gasoline and diesel. That trend is likely to accelerate with the drop in oil prices, which makes it easier to reform subsidies for oil importers and creates pressure for reform among oil exporters. And Europe is finally overhauling its common agricultural policy to largely eliminate environmentally harmful subsidies.

As for carbon pricing, it is also gaining momentum—with some 39 national and 23 subnational jurisdictions globally having implemented or scheduled to implement carbon-pricing instruments. For example, China has seven local emission-trading pilots to test possible approaches to a national scheme, and British Columbia, one of Canada's fastest-growing provinces, introduced a carbon tax in 2008.

Carbon pricing offers a potential "double dividend" by providing both environmental benefits and the possibility of reducing more distortionary taxes (such as those on labor or capital) by recycling carbon revenues. In addition, carbon constitutes

an excellent tax base, as carbon sources are concentrated and difficult to evade. In the United States, for example, tax collection covering 80 percent of emissions could be accomplished by monitoring fewer than 3,000 points (refineries, coal mines, and natural gas fields) (Metcalf and Weisbach 2009). In Sweden, which has had a carbon tax since 1992, tax evasion is less than 1 percent for carbon, much less than for the value added tax. In the United Kingdom, evasion on energy taxes is about 2 percent, much lower than the 17 percent for income tax. That is a substantial advantage for the many developing countries that struggle with tax evasion—and the wedge it introduces between the formal and informal sectors.

Yet another way to get prices right is with performance-based payments, which can be used to create incentives to preserve or increase carbon sinks, such as forests and soil. Currently, more than 300 payments for ecosystem service schemes have been established worldwide, many of them for carbon sequestration. International incentive mechanisms—such as reducing emissions from deforestation and forest degradation and other forest-based mitigation activities (also called REDD+) are being developed.

Policies to Complement Prices or to Substitute for Them When They Are Ineffective or Unchangeable

But getting prices right is not enough to ensure that low-carbon policies are acceptable, credible, and effective. Instead, policy packages need to take into account the following issues:

- *Are prices an effective instrument to trigger the desired change?* The answer depends on such factors as the availability of low-carbon alternatives or the need for long-term credibility. For instance, a carbon tax is sufficient to trigger fuel shifts in the energy sector (maybe from coal to gas) but may not be enough to generate frontier innovation in the energy or automobile industry.
- *Is it possible to change prices?* Whether prices can in fact be changed enough to trigger a response depends on the political or social acceptability of a price change. The issue may be concerns about the impact on poor people or the need to manage powerful lobbies fiercely opposed to reform.

Those two issues are linked. If price effectiveness is low, reducing emissions to a given level would require a significant price hike, which is more likely to hurt some groups or industries and is thus less acceptable. It is also possible that prices can be changed without leading to the expected impact on emissions because of missing markets, lax compliance, lack of information, or behavioral biases and cognitive failures. As a result, the policy package will need a battery of instruments—such as research and development and innovation support, performance standards and fiscal incentives for investments, financial instruments, and social policies and compensation—to create

an enabling environment for the low-carbon policies to work. This requires efforts on the following fronts.

Ensure needed technologies. A first challenge is to ensure that the needed technologies exist (a pure innovation problem) and are available at scale and at a competitive cost (a deployment problem). Existing technologies are sufficient to keep the world on a 2°C path up to about 2050, but thereafter, staying on track will require deploying technologies that are currently barely at the pilot stage or do not even exist. And the claim that a 2°C path is affordable relies on the assumption that the needed technologies will be available.

Green innovation suffers from a double market failure—environmental externalities and the same "knowledge externality" that plagues all innovation (new knowledge can be acquired at low cost by competitors). But a combination of a carbon price and broad public support for innovation will not be sufficient. Specific support toward green innovation is essential. Economic actors prefer to innovate where they have innovated before and where there is a combination of well-known demand and mature markets—a bias that favors marginal innovation in traditional domains, not radically new green innovation. Also, a carbon price is unlikely to be a sufficiently credible instrument to justify the kind of long-term, risky investments that are required for green frontier innovation. Policy makers should kick-start the transition either by temporarily supporting investments in low-carbon technologies (Acemoglu et al. 2012) or by imposing additional regulations or performance standards (Rozenberg, Vogt-Schilb, and Hallegatte 2014).

In addition, governments may even need to target specific green technologies. That specificity is justified in the case of solar, which is still more expensive than wind energy in most markets but has greater potential for reducing cost through economies of scale and for addressing the clean-energy challenge. Because of solar's current relatively high costs, it is unlikely to be massively deployed with only horizontal (nontargeted) support to carbon-free electricity production or a carbon price.

To ensure that green technologies are invented and deployed at scale, countries might supplement carbon prices (or substitute for them where they cannot yet be implemented) with a number of instruments:

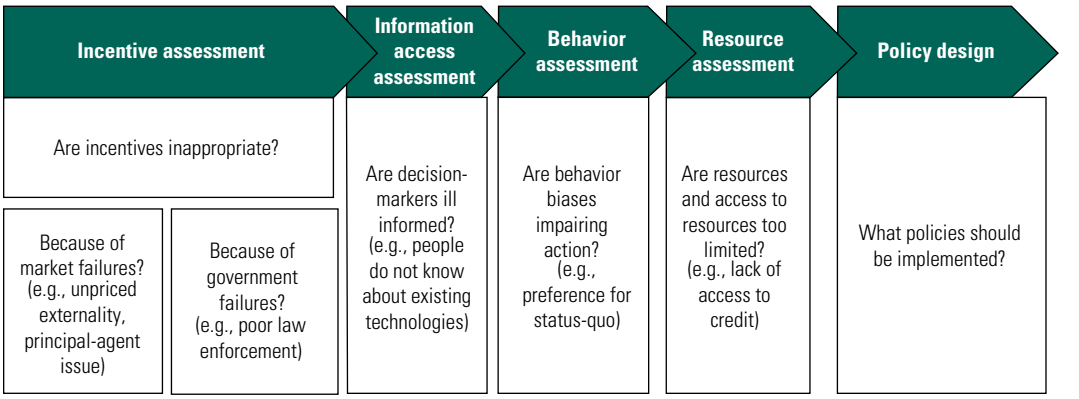
- Performance standards—such as those commonly used for cars in China, the European Union, and North America, and energy-efficient lighting or building codes (windows, ventilation, or heating and cooling systems).
- Fiscal instruments—such as auto *feebates*, which combine a surcharge (fee) on energy-inefficient cars with a rebate on more energy-efficient ones (used, for example, in a number of European countries) or a value added tax exemption for appliances or energy-efficient lighting (used, for example, in China, Ghana, and Tunisia).

- Mandates—such as renewable portfolio standards that require electricity providers to include a minimum share of clean energy in their output mix. Mandates have been used throughout the world, notably in Chile, China, Germany, and many U.S. states.
- Trade policies—such as cutting tariffs on green goods, such as solar panels, wind turbines, and energy-efficient lightbulbs as Asia Pacific Economic Cooperation countries recently agreed to do—to ensure that countries, firms, and households can access the best technologies that are available globally at an acceptable cost.
- Better institutional capacity and law enforcement—such as clarifying property rights and increasing controls and fines. In Brazil, enforcing and clarifying existing laws have proved to be an effective, low-cost strategy to reduce deforestation.

Ensure the needed infrastructure. Providing the needed infrastructure is critical for both the effectiveness of low-carbon strategies and the political acceptability of carbon pricing. For example, imposing significant fuel taxes has proved a lot more difficult in the United States than in Europe, in part because a much larger share of U.S. voters live in places unserved by easy, convenient public transportation. Infrastructure also makes a carbon price more effective by making demand more elastic to price changes. A modeling exercise for Paris shows that public transport reduces by half the carbon tax needed to achieve a given emission reduction (Avner, Rentschler, and Hallegatte 2014). Similarly, some countries have struggled to ensure that the needed electricity transmission lines and network capacity are in place to handle increased shares of renewable energy.

Account for behavioral biases and other obstacles to changing habits. But even with price incentives and available alternatives, people may still stick to old habits for a variety of reasons (figure O.4). They may do so because incentives are not effective due to

FIGURE O.4 How to Assess the Obstacles to Low-Carbon Solutions



Source: Adapted from World Bank (2013).

some market failure (for example, landlords who buy inefficient equipment because tenants pay the electricity bills) or because the incentives are just not enforced. Many countries have enacted energy-efficiency requirements for new buildings without implementing measures to enforce them.

People may also not be aware of better alternatives. Labels and certification schemes can easily provide the information consumers need to influence production technologies and promote sustainable natural resource management (for instance, for forest management).

Evidence abounds of people being "tempted" by the low price of an appliance and not paying attention to the lifetime cost of a purchase. And people tend to stick to the default option. Such behavioral biases can in fact be used to increase the adoption of green technologies. For example, a German energy company found that 94 percent of its customers stayed with the green (and more expensive) option when it was set up as the default, and only 4 percent opted for a cheaper one (the remaining 2 percent either changed suppliers or opted for a more expensive green option).

Getting the Finance to Flow—Which Will Take More than Carbon Pricing and Green Finance

Making the needed infrastructure and technologies available requires financing. In fact, most developing countries struggle with financing infrastructure provision and technological development and deployment even without the low-carbon objective. Fiscal limits constrain self-financing and overseas development aid, so the bulk of the finance challenge lies with making sure that developing countries can access more private (domestic and international) resources for long-term investment. That financing constraint extends to developing-country firms, especially small and medium-sized firms, many of which would need to invest in energy-efficient and low-carbon equipment and to access technologies adapted to local conditions.

The challenge thus is twofold: (a) to increase financing for investments in developing countries and in long-term projects, notably infrastructure, and (b) to increase the share of those investments that goes toward green projects. The low-carbon part of that challenge is an important one but should not be overestimated. According to the models reviewed by the IPCC, estimates of needed additional investment average about $400 billion per year, or about 0.5 percent of global gross domestic product. Another estimate places it at about $300 billion out of a yearly average of $6 trillion needed for overall investments by 2030 (NCE 2014).

That amount is far from negligible, but it is a small share of the total needed anyway for development and growth. Further, those investments would generate co-benefits beyond reduced climate change impacts, such as reduced air pollution that would avoid 1 million premature deaths annually by 2050 (West et al. 2013), improved agricultural

productivity, increased access to public transit, reduced congestion and traffic accidents, and greater energy security for fossil-fuel importers.

Of course, investment needs could be higher or lower, depending on how technologies develop, how early we start, and how efficient the transition is. At the sectoral level, the IPCC reports a possible range of $31 billion to $360 billion in annual investment needed for low-emission-generating technologies (renewable, nuclear, and fossil fuels with carbon capture and storage) between 2010 and 2029 and a possible range of $1 billion to $641 billion per year in energy-efficiency investments in the building, transport, and industry sectors over the same period.

Nevertheless, the point remains that the real challenge is likely to be access to financing, rather than affordability per se. Even if the absolute cost is modest relative to overall resources and represents a small increase in overall needs, financing could be difficult for countries that already struggle to generate the needed basic investments.

How can the existing financing gap be closed? Recommendations typically fall into two broad categories: making the investments more attractive and leveraging private resources to make the most of available capital. Those approaches involve well-known steps, such as improving the investment climate (making sure that regulations are clear and predictable and that the rule of law and property rights are enforced), developing local capital markets, and providing a pipeline of *bankable* projects—something that has proved difficult for many countries and is now recognized as an even greater challenge than a lack of capital. But closing the financing gap most likely also requires a deep reform of the international monetary system, including financial sector risk assessment and stress tests that have a longer time horizon and consider a broader set of risks (such as carbon exposure), along with compensation packages more attuned to long-term returns and risks.

In addition, low-carbon investments present a number of issues that must be addressed with targeted tools. Initial investments for low-carbon projects tend to be a higher share of total costs than for conventional projects, making them more sensitive to financial costs. Low-carbon projects tend to carry greater technology risk, simply because they typically rely on newer technologies. They also have higher policy risks, to the extent that they may be more dependent on government policies (such as a carbon price). In some cases, they may just be new and different, requiring investors and project managers to innovate, and may possibly lead to a *perception* of higher risk.

Thus, we see the need for rebalancing both the actual and perceived risk-adjusted returns differential between brown and green projects. The most powerful way of reducing risk perception is to make progress toward global agreements and the design of an international architecture to support climate change mitigation. That approach will go a long way toward convincing economic actors that the future will be carbon neutral. In addition, adding environmental considerations into banks' due diligence

standards would help make the financial system more sensitive to the risks embedded in *carbon-entangled* investments. As an example, the Bank of England recently agreed to examine the vulnerability that fossil-fuel assets could pose to the stability of the financial system in a carbon-constrained world.

In addition, the development of green financial products (such as green bonds) is helping mainstream low-carbon investments, connect green project developers with possible investors, and overcome the behavioral bias toward conventional investments. The green bond market has experienced rapid growth—reaching some $35 billion in 2014, up from $12 billion the year before—thereby contributing to the reallocation of resources from traditional investments to low-carbon ones. It is gaining further momentum with the development of green bond indexes by heavyweights such as Standard & Poor's, Bank of America, and Merrill Lynch.

With regard to high financial costs linked to low-carbon projects, they can be reduced through cofinancing by governments or multilateral development banks that may want to take on the *green* part of the risk. Investments can also be redirected with bank regulations that encourage commercial banks to invest in low-carbon projects. The rationale for such policies comes from the diverse mandates of central banks, which range from simply achieving price stability to contributing to wider economic and social objectives.

Managing the Transition: Protecting Poor People and Avoiding the Potential Pitfalls of Reforms

The goal of the transition is to decarbonize development rather than just reduce emissions. Hence, reforms must contribute to poverty alleviation and shared prosperity. And as with any major transition, the political economy of reforms must be managed with allowances made to those with a stake in the status quo and with good communication of the goals and benefits of the reform.

Ensuring Poor People Benefit

Fossil-fuel subsidies and artificially low energy prices are not efficient ways to boost competitiveness or help poor people. Such measures drain fiscal coffers, hurt the environment, slow the deployment of greener technologies, and chiefly benefit nonpoor people. A review of fossil-fuel subsidies in 20 countries shows that the poorest 20 percent of the population receive on average less than 8 percent of the benefits, whereas the richest 20 percent capture some 43 percent (Arze del Granado, Coady, and Gillingham 2012).

But even if removing fossil-fuel subsidies and adopting carbon pricing improve equity, those measures will also increase the price of energy and other goods (such as food), thereby reducing poor households' purchasing power. Further, higher

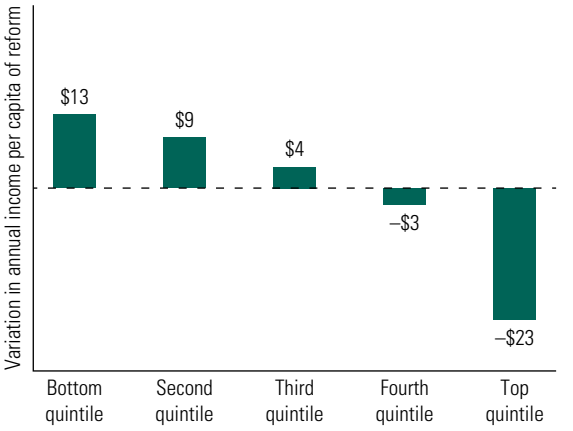
prices for modern energy could lock poor people into using solid fuels for cooking, with impacts on health, gender balance, and children's access to education (women and children spend a disproportionate amount of time collecting traditional fuels and spend more time exposed to indoor pollution). Also, industrialization has been a powerful force for poverty reduction in many countries and could theoretically be slowed by higher energy prices.

It is therefore critical to use the savings or new proceeds generated by climate policies to compensate poor people, promote poverty reduction, and boost safety nets. One way to do that is by recycling revenue through tax cuts and increasing transfers to the population—as British Columbia did to ensure that its reforms were progressive (Beck et al. 2014). Similarly, the Islamic Republic of Iran implemented a quasi-universal cash transfer (about $45 per month per capita) as part of its energy reforms (IMF 2013). A modeling exercise carried out using data from developing countries shows that taking $100 away from fossil-fuel subsidies and redistributing the money equally throughout the population would on average transfer $13 to the bottom quintile and take away $23 from the top quintile (figure O.5).

Another way to ensure that poor people benefit is with in-kind measures. Ghana's 2005 fossil-fuel subsidy reform increased the price of transport fuels by 50 percent but also included an expansion of primary health care and electrification in poor and rural areas, the large-scale distribution of efficient lightbulbs, public transport improvements, and the elimination of school fees at government-run primary and secondary schools (IMF 2013; Vagliasindi 2012).

FIGURE O.5 Using Fossil Fuel Subsidy Resources for Universal Cash Transfers Benefits Poor People

(Impact of recycling $100 from a fossil fuel subsidy to a universal cash transfer)



Source: Based on Arze del Granado, Coady, and Gillingham (2012).

Note: The figure shows the impact of reducing the fossil-fuel subsidy budget by $100 and distributing the savings as a universal cash transfer.

Redistribution has also been shown to significantly increase the odds of reforms succeeding. A review of reforms in the Middle East and North Africa classifies all reforms with cash and in-kind transfers as successful, as opposed to only 17 percent of the cases without (IMF 2013; Sdralevich, Sab, and Zouhar 2014).

Similarly, care must be taken in the design of land-use-based mitigation policies to ensure that they do not restrict access to land for the poorest people and that they respect and strengthen customary rights. A good example is Brazil's Terra Legal program, which is offering formal recognition to indigenous land and granting land titles to some 300,000 smallholders. Without such a program, REDD+ policies may benefit only richer landowners. In addition, payment for ecosystem services can directly increase the incomes of poor land users. Such programs in Brazil, Ecuador, and Guatemala aim to support poor communities, although so far evidence of their impact is limited. The hope is that by 2030, an estimated 25 million to 50 million low-income households will benefit if carbon payments are fully developed and pro-poor participation conditions secured (Milder, Scherr, and Bracer 2010).

Managing the Political Economy of Reform without Getting Captured by Vested Interests

Worries about large-scale deindustrialization and job losses—which play a big role in debates on carbon tax and cap-and-trade systems—may be overblown. Evidence from developed countries suggests that there are no discernible impacts on productivity and jobs from introducing cost-increasing environmental regulations or pricing schemes.

Indeed, pollution abatement costs represent only a small fraction of production costs for most industries, and factors such as the availability of capital and skilled labor or proximity to markets are much more important determinants of firm location and competitiveness (Copeland 2012). A detailed analysis of the European iron and steel industry shows that the impact of the European Union's emissions-trading scheme remains limited, with impacts smaller than interannual exchange rate variations (Demailly and Quirion 2008). In contrast, resources raised by carbon-pricing schemes can contribute to attracting more jobs and investments by improving more important factors, such as education and workers' skills or infrastructure, and by reducing capital and labor taxes that are more distortive than carbon pricing.

However, what is valid for relatively modest environmental regulations may not be true for stricter policies. A low-carbon transition entails a shift away from carbon-intensive sectors and technologies toward low-carbon ones. In the short to medium term, that transition means reallocating capital, labor, and rents. It cannot be done without negative impacts on some asset owners and workers. Further, those impacts

may be spatially concentrated in regions that specialize in energy-intensive or extractive industries, such as steel production or coal mining.

A key question is the extent to which those who stand to be most affected need to be compensated or protected. The answer can be based on ethical considerations: poor people are vulnerable to those changes and have a lower capacity to adjust to price changes; and some (poor or non-poor) stand to lose their investments and livelihoods because the rules of the game have changed, not because they were willfully doing the wrong thing. But there is also a pragmatic argument: compensation may be needed for political economy reasons. Climate policy gains tend to be diffuse across economic actors, and the benefits of climate change stabilization are intangible *avoided losses*, which take place mostly in the future. Those characteristics do not help create a vocal group of policy supporters (Olson 1977). In contrast, policy costs tend to be visible, immediate, and concentrated over a few industries, which may have a de facto ability to veto the reform.

A number of steps can help smooth the transition and avoid concentrating losses (either spatially or within a particular interest group). One option is to start the reforms with regulations such as performance standards that apply only to new capital. This approach is less efficient from an economic point of view than immediately introducing a carbon price. But it has the advantage of putting the economy on the right path without hurting owners of existing capital (hence, reducing resistance). Further, it creates a constituency for change, as business owners are less likely to lobby for repeal of a carbon law or against the subsequent introduction of a carbon tax if they have already invested in the new, cleaner capital. So the impact of a regulatory approach can extend past the existing election cycle. This approach also delivers emission reductions and—maybe most important in places with highly distorted prices—prepares the economy for the introduction of a carbon price or the removal of fossil-fuel subsidies, as it progressively transforms the economic system into a more efficient one that remains competitive with appropriate energy prices (Rozenberg, Vogt-Schilb, and Hallegatte 2014).

Another solution is to adopt compensation schemes. Strong social protection systems play the role of *horizontal* compensation systems, since they protect households and individuals against economic shocks. Specific instruments can also be implemented, as in Japan's support for traditional industries (such as textiles and shipbuilding) in the 1960s and 1970s. Japan relied on fiscal policies and, starting in 1978, planned capacity reduction, providing assistance to troubled firms and mitigating negative impacts on labor (Krauss 1992; Peck, Levin, and Goto 1987). The U.S. Trade Adjustment Assistance Program also provided reemployment services to displaced workers and financial assistance to manufacturers and service firms hurt by import competition. Experience from trade liberalization has shown that support such as wage subsidies to encourage hiring in the expanding sectors and unemployment insurance for the

displaced workers can effectively help mitigate most of the losses and have generally modest costs (Porto 2012; Trebilcock 2014).

Of course, governments make mistakes when trying to smooth the transition—by erring when they try to *pick the winners*, by supporting declining sectors beyond what is efficient, or by being captured by special interests. Thus, they have often taken steps to help reduce the likelihood of costly failures and capture. For example, East Asian governments used trade competitiveness as a marker for their industrial policies: public support was swiftly cut for industries that could not compete in international markets. Such a clear test may be more difficult for low-carbon technologies that by nature depend on a government policy to be attractive (whether carbon price or a regulation), but, in general, the following can help (Rodrik 2013):

- Clear and transparent criteria that determine when public support should be terminated
- An institutional design that balances flexibility (needed to adjust policies when new information is available) and predictability (so that long-term investment is possible)
- Transparency and public accountability—so that the beneficiaries of the policies are the public rather than the firms that are being supported

And Finally, Communication Matters

The political acceptability of reforms does not depend just on their impact. The *perception* of impact also matters. Thus, reforms must be anchored in a good understanding of who the stakeholders are and the nature of their fears and concerns.

Take the case of fossil-fuel subsidy reforms. A 2014 survey in the Arab Republic of Egypt showed that a whopping 70 percent of the population did not know the scale of the subsidy; worse, in Morocco, a 2010 survey found that 70 percent were unaware that energy was in fact subsidized. Thus, it was vital to raise awareness about the fact that the subsidy absorbed a huge part of government revenues (39 percent in Egypt and 17 percent in Morocco)—and the many other things that the government could achieve with those resources. Where reforms have been successful, they have often been accompanied by a communication campaign that spoke to citizens' concerns about "what's in it for me?" For example, the message of the Islamic Republic of Iran's 2010 fuel reform campaign was that the reform aimed to switch subsidies from *products* to *households*.

Wording also matters. Calling a carbon-pricing scheme a carbon *tax* suggests that its purpose is primarily to raise revenues rather than to improve welfare by creating incentives to produce and consume fewer carbon-intensive products. In fact, most schemes avoid using *carbon*, *climate*, or *tax* in their official labels, instead opting for terms such as *fee*, *premium*, or *surcharge* (Rabe and Borick 2012).

Finally, the broader benefits of reform must be communicated. In Germany, a study found that businesses were aware of higher energy taxes but not of the associated cuts in payroll taxes. But once they were informed, they were less likely to disapprove of the energy tax (Dresner et al. 2006).

In Conclusion

This report explores the types of climate policy packages needed to achieve a complete decarbonization of our economies by 2100, taking into account the many market failures, imperfections, risks, undesired distributional effects, and political economy obstacles that such a deep transition entails. It also offers a possible road map for countries that are planning their transition toward full decarbonization.

Plan ahead with an eye on the end goal. As a first step, those countries need to set up long-term objectives—say to 2050—that are consistent with the end goal of full decarbonization. Although those objectives need not be commitments, they make it possible to work backward and identify what needs to be done immediately to avoid locking in carbon-intensive patterns and increasing the odds of costly changes later on. At the same time, countries need to identify mitigation actions that bring economic, social, or health co-benefits and are therefore desirable for development and improved welfare.

From there, countries can design sector-specific shorter-term targets—to 2025 or 2030—and establish a way to track progress on the four pillars of a zero-carbon strategy: (a) decarbonization of electricity, (b) massive electrification and a switch to cleaner fuels, (c) improved efficiency and reduced waste in all sectors, and (d) improved carbon sinks. A short-term goal expressed as an economy-wide emission target is also useful but cannot replace the sectoral targets, since it could be reached with marginal actions that do not contribute sufficiently to meeting the long-term goal.

Go beyond prices. Then, countries need to craft a comprehensive policy package that includes the following elements:

- Getting prices right—including pricing carbon, which is both good fiscal and environmental policy—represents an efficient way to raise resources and can be designed to be easier to administrate and harder to evade than other taxes. It is relevant for countries at all income levels, provided that it raises revenues and that those revenues are used to support poor and vulnerable people, to reduce distortive taxes on labor and capital, and to invest in the future (such as in infrastructure or education).
- Measures to complement (or, if need be, substitute for) carbon pricing. Innovation incentives will be crucial in countries at the technology frontier. Labels, performance standards, fiscal incentives, and financial instruments have proven track records in countries at all income levels and can ensure that the best technologies are deployed to reduce energy demand and carbon emissions.

Those instruments are not only more efficient than a carbon price in triggering behavioral changes in some sectors, but they also reduce the level of the carbon price that is needed to achieve decarbonization, making it more acceptable, credible, and realistic. And making financing available will be key to implementation.

Protect poor people and avoid concentrated losses. Finally, the policy package must also include measures that make it attractive for the broader population and that avoid impacts that appear unfair. Understandably, analyses of climate policy packages typically focus on the design of the climate side of the package—the pricing instruments, the role of regulation and norms, and the support to innovation and green technology. However, the review undertaken in this report suggests that a large share of the challenge lies in the political economy. Success in stabilizing climate change will be largely determined by the ability of those accompanying policies to ensure that the decarbonization of the economic system contributes to economic development and the sustainable eradication of poverty.

Decarbonizing development is necessary to stabilize climate change. All countries are well-advised to start now, but not all will. Some countries will choose to embark on this journey sooner than others. To those countries, our message is that starting early in keeping an eye on the end goal is the way to go, along with a policy package that goes beyond prices to trigger changes in investment patterns, technologies, and behaviors and that smooths the transition for those who stand to be most affected—keeping in mind that political economy is what reforms live or die by.

References

Acemoglu, D., P. Aghion, L. Bursztyn, and D. Hemous. 2012. "The Environment and Directed Technical Change." *American Economic Review* 102 (1): 131–66.

Arze del Granado, F. Javier, D. Coady, and R. Gillingham. 2012. "The Unequal Benefits of Fuel Subsidies: A Review of Evidence for Developing Countries." *World Development* 40 (11): 2234–48.

Avner, P., J. E. Rentschler, and S. Hallegatte. 2014. "Carbon Price Efficiency: Lock-In and Path Dependence in Urban Forms and Transport Infrastructure." Policy Research Working Paper 6941, World Bank, Washington, DC.

Beck, M., N. Rivers, R. Wigle, and H. Yonezawa. 2014. "Carbon Tax and Revenue Recycling: Impacts on Households in British Columbia." Working paper, Laurier Centre for Economic Research and Policy Analysis, Waterloo, ON.

Copeland, B. 2012. "International Trade and Green Growth." World Bank, background paper for the Green Growth Knowledge Platform conference, Mexico City, January 12–13.

Demailly, D., and P. Quirion. 2008. "European Emission Trading Scheme and Competitiveness: A Case Study on the Iron and Steel Industry." *Energy Economics* 30 (4): 2009–27.

Dresner, S., L. Dunne, P. Clinch, and C. Beuermann. 2006. "Social and Political Responses to Ecological Tax Reform in Europe: An Introduction to the Special Issue." *Energy Policy* 34 (8): 895–904.

Guivarch, C., and S. Hallegatte. 2013. "2C or Not 2C?" *Global Environmental Change* 23 (1): 179–92.

IEA (International Energy Agency). 2014. *World Energy Outlook: 2014*. Paris: IEA.

IMF (International Monetary Fund). 2013. *Energy Subsidy Reform: Lessons and Implications.* Washington, DC: IMF.

Krauss, E. S. 1992. "Political Economy: Policymaking and Industrial Policy in Japan." *PS: Political Science & Politics* 25 (1): 44–57.

Metcalf, G. E., and D. Weisbach. 2009. "The Design of a Carbon Tax." *Harvard Environmental Law Review* 33: 499.

Milder, J. C., S. J. Scherr, and C. Bracer. 2010. "Trends and Future Potential of Payment for Ecosystem Services to Alleviate Rural Poverty in Developing Countries." *Ecology and Society* 15 (2): 4.

NCE (New Climate Economy). 2014. *Better Growth, Better Climate: The New Climate Economy Report*. Washington, DC: NCE.

OECD (Organisation for Economic Co-operation and Development). 2013. *Inventory of Estimated Budgetary Support and Tax Expenditures for Fossil Fuels 2013*. Paris: OECD.

Olson, M. 1977. *The Logic of Collective Action: Public Goods and the Theory of Groups*. Cambridge, MA: Harvard University Press.

Peck, M. J., R. C. Levin, and A. Goto. 1987. "Picking Losers: Public Policy toward Declining Industries in Japan." *Journal of Japanese Studies* 13 (1): 79–123.

Porto, G. G. 2012. "The Cost of Adjustment to Green Growth Policies: Lessons from Trade Adjustment Costs." Policy Research Working Paper 6237, World Bank, Washington, DC.

Rabe, B. G., and C. P. Borick. 2012. "Carbon Taxation and Policy Labeling: Experience from American States and Canadian Provinces." *Review of Policy Research* 29 (3): 358–82.

Rodrik, D. 2013. "Green Industrial Policies." Presentation at the Economics of Green Growth Workshop, Grantham Research Institute and Global Green Growth Institute, London, October 1.

Rozenberg, J., A. Vogt-Schilb, and S. Hallegatte. 2014. "Transition to Clean Capital, Irreversible Investment and Stranded Assets." Policy Research Working Paper 6859, World Bank, Washington, DC.

Sdralevich, C. A., R. Sab, and Y. Zouhar. 2014. *Subsidy Reform in the Middle East and North Africa: Recent Progress and Challenges Ahead*. Washington, DC: International Monetary Fund.

Shindell, D., J. C. I. Kuylenstierna, E. Vignati, R. van Dingenen, M. Amann, Z. Klimont, S. C. Anenberg, N. Muller, G. Janssens-Maenhout, F. Raes, J. Schwartz, G. Faluvegi, L. Pozzoli, K. Kupiainen, L. Höglund-Isaksson, L. Emberson, D. Streets, V. Ramanathan, K. Hicks, N. T. Kim Oanh, G. Milly, M. Williams, V. Demkine, and D. Fowler. 2012. "Simultaneously Mitigating Near-Term Climate Change and Improving Human Health and Food Security." *Science* 335 (3065): 183–89.

Thompson, T. M., S. Rausch, R. K. Saari, and N. E. Selin. 2014. "A Systems Approach to Evaluating the Air Quality Co-Benefits of US Carbon Policies." *Nature Climate Change* 4: 917–23.

Trebilcock, M. J. 2014. *Dealing with Losers: The Political Economy of Policy Transitions*. New York: Oxford University Press.

Vagliasindi, M. 2012. "Implementing Energy Subsidy Reforms: An Overview of the Key Issues." Policy Research Working Paper 6122, World Bank, Washington, DC.

Vogt-Schilb, A., S. Hallegatte, and C. de Gouvello. 2014. "Marginal Abatement Cost Curves and Quality of Emission Reductions: A Case Study on Brazil." *Climate Policy*. doi:10.1080/14693062.2014.953908.

West, J. J., S. J. Smith, R. A. Silva, V. Naik, Y. Zhang, Z. Adelman, M. M. Fry, S. Anenberg, L. W. Horowitz, and J.-F. Lamarque. 2013. "Co-Benefits of Mitigating Global Greenhouse Gas Emissions for Future Air Quality and Human Health." *Nature Climate Change* 3 (10): 885–89.

World Bank. 2012. *Inclusive Green Growth: The Pathway to Sustainable Development*. Washington, DC: World Bank.

———. 2013. *World Development Report 2014: Risk and Opportunity—Managing Risk for Development*. Washington, DC: World Bank.

THE SCIENCE IS UNEQUIVOCAL: stabilizing climate change implies bringing net carbon emissions to zero. And this must be done by 2100 if we are to keep climate change anywhere near the 2°C warming that world leaders have set as the maximum acceptable limit. *Decarbonizing Development: Three Steps to a Zero-Carbon Future* looks at what it would take to decarbonize the world economy by 2100 in a way that is compatible with countries' broader development goals. The book argues that the following are needed:

- **Plan ahead with an eye on the end-goal.** How best to achieve a given reduction in emissions in, say, 2030 depends on whether this is the final target or a step toward zero net emissions. If the latter, early action needs to be a mix of cheap quick fixes and costlier long-term measures to promote technology development, investment in long-lived infrastructure, and changes in how cities are built. Fortunately, many options with high potential offer immediate local co-benefits, which means early action need not represent a tradeoff with short-term development goals.

- **Go beyond prices with a policy package that triggers changes in investment patterns, technologies, and behaviors.** Carbon pricing is an efficient way to raise revenue, which can be used to support poverty reduction or reduce more distortive taxes. It is also necessary for an efficient transition toward decarbonization. But carbon pricing alone cannot solve the climate change problem, given the many market failures and behavioral biases that distort economies. Policy makers also need to adopt measures that trigger the required changes in investment patterns, behaviors, and technologies—and if carbon pricing is temporarily impossible, use these measures as a substitute.

- **Mind the political economy and smooth the transition for those who stand to be most affected.** Reforms live or die based on the political economy: a climate policy package must be attractive to a majority of voters and avoid impacts that appear unfair or are concentrated in a region, sector, or community. Thus, reforms have to smooth the transition for those who stand to be affected—by protecting vulnerable people but also avoiding concentrated losses. Getting rid of environmentally harmful subsidies and pricing carbon provide additional resources with which to improve equity, protect those affected, and, when needed, appease opponents.

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