CHAPTER

1 What Is the Best Policy Instrument for Reducing CO_2 Emissions?

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Key Messages for Policymakers

- Carbon pricing policies (carbon taxes and emissions trading systems) are easily the best instruments on the grounds of effectiveness, cost-effectiveness, and promoting clean technology investments.
- However, design details are important. Policies should be comprehensive, raise revenue, and be used in socially productive ways. Emissions trading systems also require fluid credit trading markets (i.e., a large number of market participants and institutions to enforce property rights) and price stability provisions.
- Carbon pricing policies can be challenging to implement, however, partly because of burdens on households and (trade-sensitive) industries. These burdens can be more severe than for other instruments.
- In the absence of carbon pricing, packages of regulations can be a reasonable (although not as good) alternative in the interim. However, they must be carefully designed to exploit, insofar as possible, mitigation opportunities across all sectors, and they require extensive credit trading to contain costs.
- Combining a series of "feebates" (tax/subsidy policies) may be more promising, as this circumvents the need for credit trading.
- Other policies in isolation (e.g., renewable mandates) are usually a poor substitute for carbon pricing or comprehensive regulatory/feebate packages.

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Despite the failure of the U.S. Congress to pass cap-and-trade legislation to control greenhouse gas (GHG) emissions, worldwide and even U.S. attention to developing efficient and effective policies to mitigate climate change is not waning. At the 2011 climate change meetings in Durban, South Africa (COP-17), the participating parties agreed that by 2015, they would try to negotiate an international GHG emissions control regime to begin in 2020, including both developed and developing economies. However these negotiations play out, countries will need to implement specific policies to reduce emissions, especially fossil fuel carbon dioxide (CO_2), which account for about 70 percent of global GHGs. The appropriate choice of instrument, or instruments, to reduce CO_2 emissions is, however, a complex policy decision.

For one thing, there are all sorts of instruments that could be used, ranging from market-based instruments like carbon taxes and cap-and-trade systems, to vehicle fuel economy standards, emissions standards, and incentives for renewable fuels (see Box 1.1 for an explanation of the main options).

Box 1.1. Main Alternative Instruments for Mitigating CO_2 Emissions

Carbon taxes. Ideally, these taxes are applied upstream in the fossil fuel supply chain in proportion to the carbon content of fuels. Alternatively, they could be levied on CO_2 emissions released from major industrial smokestacks.

Cap-and-trade systems. These policies put a cap on emissions by requiring that covered firms hold permits for each tonne of (potential or actual) emissions. The government restricts the quantity of allowances, and trading among covered sources establishes a market price for allowances. Again, these policies could be applied upstream to the carbon content of fuels or at the point of emissions releases.

Excise taxes on individual fuels (e.g., coal), electricity, or vehicles.

Energy efficiency standards. Applied to vehicles, these policies set minimum requirements on the average fuel economy (kilometers per liter) of vehicles sold by different firms or (almost equivalently) a maximum rate for average CO_2 per kilometer across vehicle sales. Ideally, credit trading would allow some producers (specializing in large vehicles) to fall short of the standard by purchasing credits from others that go beyond the standard. Standards can also be applied to improve the energy efficiency of new buildings, household appliances, and other electricity-using durable goods.

Emissions standards. For the power sector, this policy imposes a ceiling on the maximum allowable CO_2 per kilowatt hour (kWh), averaged across each generator's plants. Again, flexibility can be provided by allowing emissions-intensive generators to fall short of the standard by purchasing credits from other generators that go beyond the standard.

Box 1.1. (*continued*)

Incentives for renewable fuels. Policies to promote generation from renewables include renewable portfolio standards (minimum shares for renewables in a generator's fuel mix), subsidies for renewable generation, and feed-in tariffs (guaranteed prices for renewable generation).

Feebates. For vehicle sales, feebates apply fees to new vehicles in proportion to the difference between their CO_2 per kilometer and a "pivot point" level and corresponding rebates (or subsidies) to vehicles with CO_2 per kilometer below the pivot point. Similarly, in the power sector, feebates impose a per-kWh charge on generators in proportion to any difference between their average CO_2 per kWh and the pivot point and a rebate to generators with CO_2 per kWh below the pivot point. Feebates can be designed to raise some revenue, or be revenue neutral, depending on whether the pivot point is below or at the industry average emission rate.

Regulatory combinations. These involve a set of independent regulations designed to exploit many of the emission-reduction opportunities that would be exploited under comprehensive emissions pricing. For example, the combination might include an emissions standard for the power sector and various standards for the energy efficiency of vehicles and electricity-using durables. Alternatively, the feebate analogs to these regulations might be combined in a policy package.

Source: Authors.

Moreover, policymakers may be concerned about multiple criteria, including the following:

- *Effectiveness* in terms of reducing CO_2 emissions in the near term.
- *Economic costs*—a *cost-effective* policy is one that minimizes the burden on the economy from a given emissions reduction (accounting for use of any government revenues raised).
- *Ability to deal with uncertainty* over future fuel prices, the availability of emissions-saving technologies, and so forth.
- *Distributional impacts* across income groups and industries, which matter for fairness, competitiveness, and acceptability.
- *Promotion of clean technology development and deployment,* which matters for long-term effectiveness.

This chapter provides a framework for evaluating alternative policy instruments against the above criteria and understanding the potentially strong case for fiscal instruments (i.e., carbon taxes or their cap-and-trade equivalents with allowance auctions). The following five sections take each of the above criteria in turn, and a summary matrix at the end of the chapter ranks all the policies against the different criteria. The discussion mostly draws on insights from the economics literature on instrument choice (see Suggested Readings).

For clarity, policies are compared (approximately) for the same (explicit or implicit) price they place on CO_2 emissions or the same impact they have on energy prices. For example, when an electricity tax is compared with an economy-wide CO_2 tax, the policies are assumed to have about the same effect on electricity prices. This means that both policies can be cost-effective *for the emissions reductions they achieve,* but those reductions will be (much) larger under the CO_2 tax.

The discussion is not fully comprehensive. Many other policies are often rationalized on climate grounds (e.g., biofuel mandates or tax credits for hybrid vehicles), although their environmental effectiveness is typically on a smaller scale than the instruments considered here. And our criteria are not exhaustive: Policymakers may also care about the ease of negotiating international agreements and the development of international carbon markets (to facilitate financial and technology flows). The first is difficult to gauge, and in principle, all market-based and regulatory approaches could promote carbon markets through appropriate crediting provisions, though the market breadth will depend on the portion of domestic emissions covered by the mitigation instrument.[1]

Environmental Effectiveness

A policy's effectiveness depends on its ability to exploit possibilities for reducing (energy-related) CO_2 emissions across the economy. It is helpful to group the main possibilities into the following four categories:

- *Power sector fuel mix*. Reducing average CO_2 emissions per kilowatt hour (kWh) of power generation through switching from carbon-intensive fuels (coal) to less carbon-intensive fuels (natural gas, fuel oil) or zero-carbon fuels (nuclear, hydro, wind, solar, geothermal). Emissions intensity can also be reduced through technologies to improve plant efficiency

[1] Other possible criteria not considered here include administrative costs and the ease and accuracy of monitoring and enforcement (see Chapter 2 for some discussion on this topic). A further caveat is that the policies we discuss are broad-brush rather than finely detailed. Cap-and-trade systems implemented to date have involved considerable complexity (see Chapter 8), although the same may be true of other policies, such as carbon taxes, as they emerge from the legislative and regulatory process. Whether these details (e.g., on exempt sectors or earmarking of policy revenues) matter for the general conclusions drawn here would need careful study.

(i.e., reducing fuel requirements per kWh of generation). And carbon capture and storage (CCS) technologies may eventually prove viable in preventing CO_2 releases from fossil fuel plants.

- *Power sector output.* Reducing residential and industrial (including commercial) electricity demand through electricity-saving technologies (e.g., compact fluorescent lamps) as well as reduced use of electricity-using durables (e.g., economizing on the use of air conditioners).[2]
- *Direct non-electricity fuel use in homes and industry.* Reducing direct usage of fuels (e.g., natural gas) in homes, shops, factories, and offices.
- *Transportation fuels.* Reducing consumption of transportation fuels through reducing vehicle miles travelled and improving average vehicle fuel economy.

Market-Based Policies

Comprehensive (upstream) policies. A highly effective policy for reducing CO_2 emissions is a carbon tax applied upstream in the fossil fuel supply chain in proportion to the carbon content of each fuel (with refunds for any downstream capture of emissions by CCS). This tax system fully covers potential releases of CO_2 from later fuel combustion. To the extent the emissions tax is passed forward, it leads to higher prices for fossil fuels (especially coal, but also natural gas and petroleum products) as well as electricity. These higher energy prices encourage all of the above emission-reduction opportunities.

Cap-and-trade systems. These can be applied to the same base as the carbon tax and are therefore about equally effective over time. That is, as the value of allowances (i.e., the emissions price) is reflected in fuel and electricity prices, the policy will exploit the same emissions reduction opportunities as under the carbon tax.

Market-based policies with partial coverage (downstream). Another possibility is market-based policies focused at the point of emissions releases by large power and industrial plants. These policies are less effective at reducing emissions than upstream systems unless they are accompanied by measures to address transportation fuels, home heating fuels, and

[2] One caveat here is that electricity conservation tends to hit the most expensive (i.e., marginal) fuels first, which may be renewables or natural gas, rather than the highest carbon-emitting fuel, hence dampening the effect on emissions.

small-scale industrial sources. For example, by itself, the EU Emissions Trading Scheme covers about half of energy-related CO_2 emissions.[3]

Other energy taxes. Other energy taxes tend to be relatively ineffective at reducing CO_2 (see Chapter 2). Excise taxes on residential and industrial electricity use only exploit one of the four main emissions reduction opportunities.[4] Taxes on vehicle ownership are less effective still—even within the transport sector, they do not encourage people to drive a given vehicle less and may not (depending on how they are designed) create much demand for fuel-efficient vehicles. And while a coal tax is effective at reducing the most carbon-intensive fuel, it misses out on some opportunities exploited by a carbon tax, such as shifting from natural gas and fuel oil to nuclear and renewables and mitigation options outside of the power sector.

Direct Regulations

Regulatory policies by themselves can be expected to have (very) limited effects (particularly at the same implicit CO_2 price as the market-based instruments). These instruments need to be combined in far-reaching policy packages to achieve anything close to the effectiveness of comprehensive market-based policies. We distinguish among regulations focusing on increasing particular types of energy use (renewables), reducing carbon emissions, and reducing energy use.

Incentives for renewable generation. While there could be a rationale for transitory policies to promote renewables due to broader, technology-related market failures (see below), usually this is—or at least should be—as a *complement* to, not a *substitute* for, broader pricing instruments. These policies in isolation are not very effective relative to comprehensive pricing policies. They do nothing to reduce emissions outside of the power sector. At best, they only have weak incentives for electricity conservation as they do not involve the pass-through of carbon tax revenue or allowance value in higher generation prices.[5] And even within the power sector, they do

[3] Extending the EU emissions price to all emissions sources would not double emissions reductions, however. This is because most of the low-cost options for reducing CO_2 (for the European Union) are in the power sector or, put another way, emissions in the noncovered sector are less responsive to pricing than emissions that are already covered.

[4] These taxes are mandatory in the European Union under Energy Directive 2003/96/EC, although there are current discussions to revise this directive to target carbon emissions more directly.

[5] Under a renewable mandate, generators face higher average production costs per kWh because they shift away from their least-cost generation mix toward a cleaner, but more costly, generation mix. This also happens under market-based approaches applied at the point of emissions releases. In addition, however, average costs to generators, and hence generation prices, rise because generators must either pay a tax on their remaining CO_2 emissions per kWh or buy allowances to cover those emissions. In an upstream market-based system, carbon tax revenues or allowance value are already captured in the higher fuel prices paid by generators, which in turn are passed forward into electricity prices.

not exploit emissions reductions from replacing coal with natural gas and fuel oil or for switching from these fuels to nuclear.

Broader policies to decarbonize power generation. An industry-wide standard for CO_2 per kWh is a more effective approach than a renewables incentive policy because it encourages *all* possibilities for altering the generation mix to lower CO_2 emissions (not just substitution toward renewables) as well as improvements in plant efficiency. (As noted later, however, these types of regulatory policies need to be accompanied by extensive credit trading provisions to keep down their costs.) An emissions standard is closely related to the Clean Energy Standard, variants of which are currently under consideration in the United States. This policy sets minimum requirements on the share of zero-carbon fuels in power generation, but allows partial credits for fuels with intermediate carbon intensity.[6]

- There is also a pricing variant of the emissions standard, known as a feebate (see Box 1.1). This policy exploits the same incentives for reducing CO_2 per kWh as an emissions standard, but with some possible advantages in terms of cost-effectiveness. The feebate is approximately equivalent to a tax on carbon emissions from the power sector, with revenues used to finance a per-unit subsidy for electricity production. More generally if the pivot point is reduced (i.e., the threshold CO_2 per kWh, which determines whether firms pay fees or receive rebates), the feebate has a greater impact on electricity prices (because more generators are paying fees than are receiving subsidies). In this case, the policy is equivalent to an electricity emissions tax, with a fraction of (rather than all) revenues used for a production subsidy.

Energy efficiency policies. Regulatory policies can also reduce the demand for electricity, and direct fuel usage, through setting standards for energy intensity. For example, several countries (e.g., China, Japan, the United States) set standards for the average fuel economy (kilometers per liter or equivalent) of new passenger vehicle fleets. Building codes are also common, as are standards for the energy usage rate of household appliances (e.g., refrigerators), lighting, and heating/cooling equipment. Again, feebates represent a pricing variant of these policies. For example, if applied to passenger vehicles, manufacturers selling relatively fuel-inefficient vehicles would pay a fee in proportion to the difference between the average fuel consumption rate (or CO_2 per kilometer) of their fleet and that for the industry average, multiplied by vehicle sales, while manufacturers with relatively fuel-efficient fleets would receive a corresponding subsidy.

[6] For example, a required share of 20 percent for zero-carbon fuels might be met, say, by a combined share of 10 percent from renewables, hydro, and nuclear and 20 percent from natural gas, if the latter receives half a credit.

- In the power sector, efficiency standards are less effective at reducing emissions than market-based carbon policies. Potentially the most important reason is that efficiency standards do not provide incentives for power generators to reduce CO_2 emissions per kWh. Another reason is that they do not encourage a reduction in the use of energy-using durables and other goods. Furthermore, a range of energy-intensive goods have typically been exempt from regulations (e.g., small appliances, audio and entertainment equipment, assembly lines), yet higher energy prices would provide across-the-board incentives for more efficient versions of these products. And, at least for some transitory period, standards on new products raise their price relative to used products, which can delay the retirement of old (relatively polluting) products. In contrast, higher energy prices will tend to accelerate retirement of older (energy-inefficient) products.

- In the transport sector, efficiency standards are basically identical to CO_2 standards (on a per-kilometer or tonne-kilometer basis) because this sector uses mostly oil-based fuels. These instruments are less efficient than market-based policies. Higher fuel prices provide incentives to reduce vehicle kilometers driven (by raising fuel costs per kilometer) and to buy more fuel-efficient vehicles: Fuel economy standards (or feebates or CO_2 standards) only exploit the latter margin of behavior, which, as a rough rule of thumb, might reduce their effectiveness by about 50 percent relative to a fuel tax.[7]

Regulatory combinations. In short, regulatory policies by themselves provide only limited incentives for reducing CO_2 emissions. However, regulatory (or feebate) combinations, involving a package of measures to reduce the emissions intensity of power generation and to improve the efficiency of major energy-using durables (buildings, vehicles, household appliances), may go a fairly long way in matching the environmental effectiveness of comprehensive, market-based policies. Nonetheless, even under these combination policies, not all emissions reduction opportunities—in particular reduced use of vehicles and other energy-using durables—will be exploited.

The Cost-Effectiveness of Different Policies

A cost-effective policy achieves a given emissions reduction at lowest overall cost to the economy. This matters, not only for its own sake, but also for enhancing prospects that the policy will be sustained over time. To start with, our discussion focuses on costs within the energy sector. These costs are

[7] In fact, by lowering fuel costs per kilometer, the latter policies tend to encourage more vehicle use, although evidence for the United States suggests that this “rebound effect” is relatively modest.

minimized when the cost of the last tonne of emissions reduced is equated across all firms and households. Later, a broader and more appropriate notion of economic cost is considered, which has important implications for the use of revenues from mitigation policies. Box 1.2 provides more discussion of how to think about costs from an economic perspective.

Box 1.2. Understanding the Costs of Emissions Mitigation

The economic, or "welfare," costs of an emissions mitigation policy summarize the costs of all the different, individual actions taken to reduce emissions (leaving environmental benefits aside). These would include, for example, such direct costs as producing electricity with cleaner but more expensive fuels. They also include the less obvious costs to households from driving less, or utilizing fewer energy-using products, than they would otherwise prefer.

It is often easier to define welfare costs by what they are not. They are not measured in terms of *job losses* in industries most directly affected by new policies. Many of those jobs are usually made up by other sectors after a period of adjustment. Welfare costs need not be closely related to changes in gross domestic product (GDP), either. For example, a regulation that leads to the use of a higher priced alternative and raises product prices may actually increase GDP, even though it has positive welfare cost.

Transfers between one segment of society (e.g., consumers) and another (e.g., producers, the government) are not welfare costs. This means that tax revenues raised through carbon taxes themselves are not directly included in welfare costs, nor are outlays on renewable subsidies. As explained below, however, to the extent that new revenue gains/losses imply changes in the rates of broader taxes that distort the economy (e.g., taxes that reduce the return to work effort and capital accumulation), there will be consequences for the overall welfare cost of the policy.

The welfare cost concept has been endorsed by governments around the world for purposes of evaluating regulations, government investments, taxes, and other policies. In the United States, a series of executive orders since the 1970s has required government agencies to perform hundreds of cost-benefit analyses a year, using welfare costs (and welfare benefits) to determine whether their planned "major" regulations are justified from society's perspective.

Source: Authors.

Market-Based versus Regulatory Policies: A First Look

Market-based policies are cost-effective in the sense that all emissions sources covered under the policy are priced at the same rate. Therefore, all firms and households face the same incentives to alter their behavior in ways to reduce emissions up to the point where the cost of the last tonne reduced (e.g., the cost of additional fuel switching in the power sector or the costs to motorists of forgoing trips) equals the price on emissions. For emissions trading systems, cost-effectiveness requires fluid markets, which may not be possible for countries lacking institutions for enforcing property rights or lacking large numbers of market participants.[8]

Market-based policies with and without full coverage of emissions (including, for example, taxes on electricity or individual fuels) are called cost-effective here because they minimize costs within the energy sector *for the emissions reductions that they achieve*. An alternative way of comparing policies is to compare their costs, *for the same effectiveness in terms of reducing emissions*. Under this latter comparison, the market-based policies with partial emissions coverage are not viewed as cost-effective. To achieve the same emissions reduction as under the policy with full coverage, they place too much of the burden on covered sources and none of the burden on other sources, rather than striking the cost-effective balance of reductions across all emissions sources.

Regarding regulatory policies, such as emissions standards and energy efficiency standards, besides their limited effectiveness, they can also perform poorly on cost-effectiveness grounds *if they force all firms to meet the same standard*. For example, it will be relatively costly for a generator heavily dependent on coal to meet a standard for average CO_2 per kWh, compared with a generator that is less dependent on coal. To promote cost-effectiveness, these standards need to be accompanied by extensive credit-trading provisions. These provisions would allow the coal-intensive generator to have higher CO_2 per kWh than the standard by purchasing credits awarded to another generator with CO_2 per kWh lower than the standard. Similarly, under a vehicle fuel economy standard, trading provisions would allow manufacturers or sellers specializing in relatively large vehicles to fall short of the average fuel economy requirement by purchasing credits from a manufacturer specializing in relatively small vehicles for whom exceeding the standard (to obtain credits) is relatively inexpensive. As noted above, credit trading works well only if trading markets are well developed.

However, a more direct way to promote cost-effectiveness, which circumvents the need for any credit trading, is simply to use pricing variants of these policies. For example, under the power sector feebate, coal-intensive generators will opt to pay fees to the government (and exceed the pivot point CO_2 per kWh), while relatively clean generators will receive rebates (for reducing CO_2 per kWh below the pivot point).[9] It is important, however, that

[8] Even well-developed markets can sometimes be subject to manipulation.
[9] In effect, feebates are the tax analogue to emissions or efficiency standards with perfect credit trading.

the tax saved by relatively dirty/energy-inefficient producers from reducing CO_2 by a tonne is the same as the extra subsidy received by relatively clean/energy-efficient producers for reducing CO_2 by a tonne. If not, there will be an excessively costly pattern of emissions reductions across the two types of producers as they face different rewards for reducing emissions.

More generally, for a regulatory combination to be cost-effective, it requires not only credit trading within sectors, but also across sectors, to establish a single price on CO_2 emissions across the economy. Without a uniform price, there is a risk that too much of the burden of emissions reductions will be borne by one sector and too little by another. Similarly, in a feebate package, the implicit price on emissions should be harmonized across sectors.

Box 1.3 discusses some modeling results for the United States that underscore some of the points made so far. It also notes the potential for redundancies when (as is common in practice) governments implement a suite of related policies.

Box 1.3. Modeling Results on the Effectiveness and Cost-Effectiveness of Alternative CO_2 Mitigation Policies

The figure below summarizes a recent study on the projected effectiveness of various policies at reducing domestic, U.S. CO_2 emissions, cumulated over the 2010–2030 period (the height of the bars), and the average welfare costs per tonne reduced, as defined in Box 1.2, over the same period (indicated by the color of the bars). See Krupnick and others (2010), pp. 149–152, for a definition of all the policies. Here we highlight just a few points.

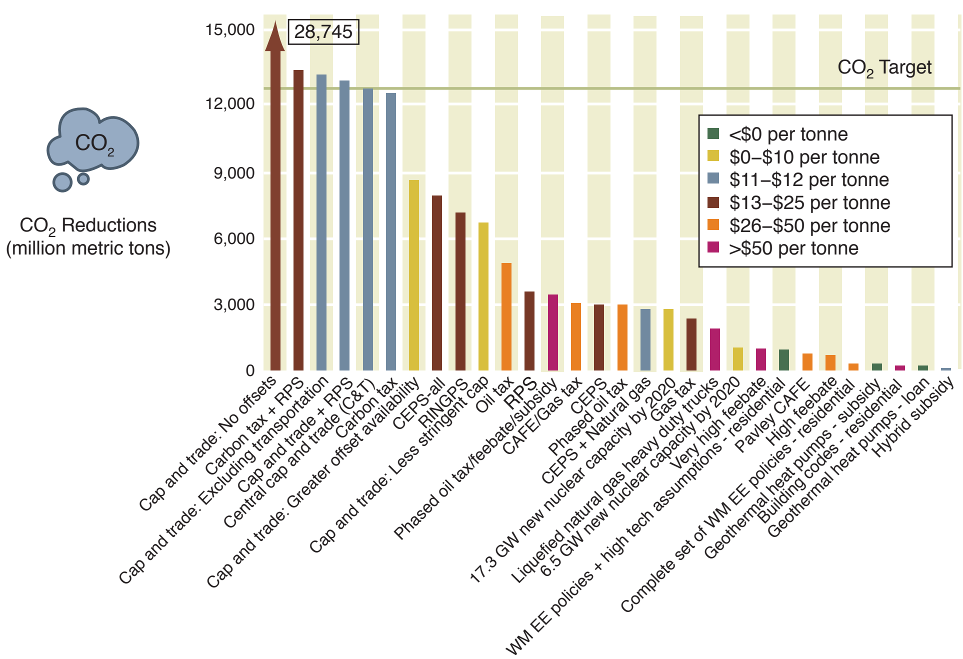
Not surprisingly, comprehensive carbon taxes and cap-and-trade systems of the scale envisioned in (unsuccessful) federal cap-and-trade bills (and indicated by the set of blue, relatively tall bars) are found to be the most effective at reducing domestic emissions. The average costs reduced are also relatively low for these policies ($11 to $12 per tonne of CO_2 reduced, in 2007 U.S. dollars). Combining a cap-and-trade policy with a renewable portfolio standard (RPS) has essentially no effect on emissions (i.e., the RPS is redundant) as emissions are fixed by a series of annual caps. If domestic sources must meet the same caps, but without any purchases of emissions offsets (offsets are defined below), the domestic emission reduction is larger, though average costs per tonne rise (the extreme left-hand bar).

Emissions reductions under the RPS by itself are only about 25 percent of those under broad pricing policies. But allowing credits for incremental natural gas (RINGPS) or credits for all fuels with lower carbon intensity than coal—the Clean Energy Portfolio Standard (CEPS-ALL)—substantially improves effectiveness of up to about 50 to 60 percent of that under broader emissions pricing policies.

Box 1.3. (***continued***)

However, even very large increases in gasoline taxes (of about US$1 per gallon or US$0.26 per liter) reduce emissions by only a minor fraction of the reduction under broad pricing policies. Most obviously, this policy only covers emissions from road transport. In addition, options for substituting clean fuels for conventional fossil fuels in passenger vehicles are limited (compared with fuel switching possibilities in the power sector). And manufacturers are already incorporating advanced fuel-saving technologies to meet escalating Corporate Average Fuel Economy (CAFE) standards.

Another policy redundancy—in the presence of binding CAFE requirements—is subsidies for hybrid vehicles. These subsidies lead to a greater penetration of hybrids, but manufacturers can then ease up on improvements for conventional gasoline vehicles while still meeting the same fleet-wide average fuel economy standard.



Source: Authors, selected cases from Krupnick and others (2010) based on simulating a variant of the U.S. Energy Information Agency's National Energy Modeling System.

A Closer Look at Cost-Effectiveness

Comprehensive carbon taxes, as well as cap-and-trade systems with allowance auctions, provide a potentially significant source of annual government revenue—perhaps in the order of 1 percent of GDP for the United States and over 2 percent for China. How this revenue is used will have important implications for the broader costs of market-based policies beyond the costs in energy markets.

In particular, if these revenue sources are used to reduce other taxes that distort the broader economy, then this can help to substantially reduce overall policy costs. Taxes on labor income, for example, distort the labor market by lowering the returns to labor force participation and effort. Taxes on corporate income and income from household savings distort the capital market by reducing capital accumulation below levels that would otherwise maximize economic efficiency. Using climate policy revenues to cut these taxes therefore produces broader benefits to the economy.

Despite these potential benefits, the overall costs of carbon taxes, as well as cap-and-trade systems with allowance auctions, are likely to be positive (although, up to a point, environmental benefits will be much larger than these costs). This is because there is a counteracting effect that offsets the benefits from revenue recycling—as carbon taxes and cap-and-trade systems drive up energy prices, they tend to contract (albeit very slightly) the overall level of economic activity, which in turn has a (slightly) depressing effect on employment and investment.

The main point here (as discussed further in Chapter 2) is that how revenues are used can have important implications for the overall costs of market-based instruments. If revenues from carbon taxes are used in socially productive ways, such as to reduce distortionary taxes elsewhere in the economy or fund socially desirable spending, then this substantially lowers policy costs. Similarly, for cap-and-trade systems to be cost-effective, allowances need to be auctioned and revenues need to be used productively. If instead allowances are given away for free in a lump-sum fashion to industry, overall (net) policy costs are substantially higher as a valuable revenue-recycling benefit is given up. In fact, allocating all the allowances free to affected industries will greatly overcompensate them, given that most of the allowance price tends to be paid by households in the form of higher energy prices rather than paid by firms in the form of lower producer prices.

If revenues from taxes or cap-and-trade are not used wisely, certain regulatory combinations may conceivably perform better on overall cost-effectiveness grounds than market-based policies. In this regard, a "benefit" of regulatory instruments is that they tend to have a weaker effect on energy prices than market-based policies because they do not involve the pass-through of tax revenues or allowance rents in higher prices. Consequently, regulatory policies can do less harm to overall economic activity than market-based approaches that do not exploit the revenue-recycling benefit. For most countries, the best policy of all on cost-effectiveness grounds is a carbon tax, or auctioned cap-and-trade system, with revenues used to cut broader distortionary taxes, either directly or indirectly through deficit reduction (which avoids the need for raising other taxes).

Dealing with Uncertainty

The future costs of emissions control instruments will also depend on the future prices of clean and dirty fuels and the future cost of emissions-saving technologies. Considerable uncertainty surrounds these factors. Given the strong desire of environmental groups and others to fix the quantities of emissions (or renewables), such groups tend to favor a cap-and-trade system (and quantity mandates) rather than a fixed price system (e.g., a tax), as the latter lets quantities vary over time as uncertainties are resolved.[10] Yet, in the presence of uncertainty, there is a cost to fixing the emissions limit (for covered sources) involving (1) allowance price volatility that causes too little abatement in some years and too much in others from a cost-effectiveness viewpoint and (2) the slowing of long-term, clean technology investments. There are ways to deal with these concerns, but only if policymakers are willing to relax rigid annual emissions controls.

Taxes versus Cap-and-Trade

Annual emissions targets leave the price of allowances in cap-and-trade systems to be determined by the market. Prices are relatively high in periods when meeting the cap is costly (e.g., in times of high energy demand or high prices for clean fuels) and vice versa in periods when the costs of meeting the cap are relatively moderate. Reducing price volatility can help to lower program costs over time for a given cumulative reduction in emissions. With a stable emissions price (or rather, one rising at the interest rate), emissions reductions will be greater in periods when the costs of those reductions are relatively low and vice versa when controlling emissions is relatively costly: in this way, stable prices help to equate the (discounted) costs of incremental abatement in different years. Stable emissions prices may also create business conditions that are more conducive to investments in clean technologies (e.g., wind and solar plants) with high upfront costs and long-range payoffs in terms of emissions reductions.

One way to limit price volatility in a cap-and-trade system is to allow firms to bank allowances (i.e., carry forward allowances to cover emissions in future

[10] Environmental groups have an aspiration for environmental certainty, implying a preference for quantity over price/cost targets. However, unless a cap-and-trade policy covers all sources of CO_2, such certainty cannot be attained. And even if a given country fully covers its sources with such a program, carbon leakage to countries without a policy will create quantity uncertainty.

years rather than turning them all in now), which enables them to do extra abatement in periods when emissions reduction costs are low. Another is to allow advance auctions where firms can buy permits at today's prices for use several years from now (if they anticipate higher permit prices). Furthermore, firms might borrow allowances (i.e., use some allowances for future periods now), which enables them to do less abatement when emissions control costs are high.

Another possibility is to combine a cap-and-trade system with a price collar. In periods when allowance prices hit a ceiling level, the government could sell extra allowances to the market at that ceiling price, thereby relaxing the emissions cap, while in periods when allowance prices fall to a floor level, the government could step in and buy allowances back at the floor price, thereby tightening the emissions cap.

Yet another possibility is to allow covered sources to purchase international emission offsets (e.g., through the Clean Development Mechanism), which helps to put a ceiling on the domestic allowance price. Offset provisions enable domestic firms to claim credits by paying for (cheaper) mitigation projects, typically in developing economies. Offsets are not always real, however (i.e., the developing economy project may have occurred anyway without the offset payment), in which case environmental effectiveness is undermined (and the domestic country makes a transfer to the developing economy for no emissions benefit). Preserving policy credibility may therefore require stringent verification requirements for offsets, implying a correspondingly higher emissions price and domestic abatement cost.

However, the best way to provide price stability is simply to implement a carbon tax (with the price rising automatically at a fixed annual rate) instead of a cap-and-trade system. The tax provides full (rather than partial) price stability, without the need for complicating design provisions.

The drawback of price stability is that policymakers lose control of annual CO_2 emissions from covered sources—annual targets for specific years have so far underpinned international negotiations over climate mitigation. However, one year's emissions by one country have essentially no impact on future global warming—rather, this is determined by the historical accumulation of global emissions since the industrial era. If policymakers continue to negotiate over quantities rather than emissions pricing, a better approach than annual targets might be to focus on carbon budgets. These budgets would fix allowable cumulative emissions over a multiyear period (say, 10 years), leaving countries with flexibility over annual emissions.

Other Policies

Following similar logic, price-based alternatives to regulatory policies are better able to handle uncertainty over future abatement costs, although at the (political) expense of variability in year-to-year emissions. For example, a feebate for the power sector (with the emissions price growing at the rate of interest) will equate the (present value) of the incremental cost of abatement in different years. A strict CO_2 per kWh standard each year would not be cost-effective, as the incremental costs of meeting the same standard are likely to vary over time as fuel prices, and so forth, change. Again, this problem could be addressed, at least in part, through price stability provisions (banking and borrowing of credits, price ceilings, floors).

Incidence and Competitiveness

The burden of climate policies on households (especially poor households), firms, and the implications for the competitiveness of industries producing tradable products are often major concerns to policymakers. These burdens stem from the effect of policies on energy prices, particularly electricity prices, but also on fuels directly consumed by households and firms. Chapter 2 discusses these issues in the context of carbon taxes, along with possibilities for offsetting household and industry burdens. Here we simply compare the seriousness of distributional and competitiveness effects of other instruments relative to those for carbon taxes.

Burden on Households

In developed economies, poorer households tend to spend a relatively large portion of their income on electricity, transportation fuels, and fuels for heating and cooking. This means that the burden—relative to income—of the higher energy prices (caused by comprehensive carbon pricing policies) is greater for lower income households, which runs counter to broader government efforts to moderate income inequality. For developing economies, the burden-to-income ratio might be lower for relatively low-income groups if they do not own vehicles or have access to electricity. Nonetheless, any new policy that potentially reduces living standards in absolute terms for the poor may require offsetting compensation.

Clearly, the burden on low-income households will be less severe for market-based instruments with partial coverage or for individual taxes on electricity or vehicles, but these policies have very limited environmental effects. More important is the distinction between market-based policies and regulatory combination policies, or feebate combinations, with broad environmental effectiveness. As already mentioned, market-based policies can have a much bigger effect on energy prices, as they involve the pass-through of large revenues from taxation or permit auctions or of allowance rents (if not auctioned) into higher prices.

Burden on Firms

Any policy that raises the price of products—which includes most policies to reduce carbon emissions—will have effects across sectors that compete with one another (such as coal versus natural gas sales to electricity producers) and/or compete with countries that do not apply similar charges. The industries hit hardest are energy-intensive, trade-exposed sectors, where there are limits on the pass-through of input costs to product prices. For example, higher electricity prices will hurt those industries that are heavy electricity users, like aluminum producers and oil refiners. Aside from the political problems posed by firms that fear being outcompeted, there are concerns about job outsourcing and carbon leakage.[11]

Implications for Instrument Choice

In fact, distributional incidence may provide a second reason for revisiting the case for market-based instruments over regulatory and feebate approaches (the first reason being the possibility that the actual or potential revenue recycling benefits from pricing instruments are not exploited). If households and industry cannot be adequately compensated under market-based policies, it may well be that the practical benefits of avoiding large increases in energy prices through using other instruments outweigh the drawbacks of those instruments (in terms of missing some emissions reduction opportunities).

Naturally, there are caveats here. As noted, regulatory and feebate approaches would need to be comprehensive and harmonized to provide the same rewards for additional emissions reductions across different sectors. Moreover, at more stringent levels of abatement, as opposed to moderate abatement levels, the relative discrepancy in energy price impacts between market-based and other approaches becomes less pronounced.[12] That is, the practical advantages of other instruments diminish as the policy is tightened over time. Even if, for example, feebates were the preferred instrument

[11] While difficult to project accurately, the problem of this source of emissions leakage should not be overstated. For example (leaving aside well-integrated regions like the European Union), reductions in transportation fuels in one country or shifts to cleaner power-generation fuels are likely to cause little offsetting increases in emissions in other countries (at least in the absence of significant reductions in world fossil fuel prices).

[12] For example, at higher tax levels, emissions per kWh are lower, implying a smaller impact on electricity prices from further tax increases.

initially, ideally there would be a progressive transition to market-based instruments as the feasibility of the latter improves.

Nonetheless, the ideal approach would be to start with a market-based instrument but provide the needed compensation to adversely affected groups—so long as this compensation does not compromise policy costs too much. As discussed in Chapter 2, there are some promising ways to do this.

Promoting Clean Technology Development and Deployment

In this chapter, we have examined alternative instruments to correct for the market failure of uninternalized externalities associated with CO_2 emissions. Such instruments, particularly carbon taxes or a cap-and-trade approach, also stimulate the creation and deployment of new technologies—any new way of reducing CO_2 emissions at a cheaper cost will be of interest to emitters if the cost of acquiring and using that technology is less than their outlays for the CO_2 emissions such technologies would displace. Broad-based pricing instruments provide incentives for clean technology development and deployment across all sectors of the economy.

However, uncertainty over future emissions prices—as in cap-and-trade systems lacking price stability provisions or carbon taxes where future tax rates are not well defined—may deter clean technology investments. Moreover, if the tax or cap-and-trade system has partial, rather than full, coverage, it will lack the across-the-board technology incentives provided by more comprehensive pricing. Similarly, taxes on electricity or individual fuels incentivize only a narrow range of clean technology investments.

Feebates or emissions standards are superior to specific technology standards (e.g., CCS) because, for the latter, once the targeted technology is adopted, the incentive to develop new technologies stops.[13] But again, the former needs to be implemented and coordinated across sectors to provide the broader technology incentives that are automatic under comprehensive carbon pricing policies.

Even with CO_2 emissions comprehensively priced, there are reasons for believing that efforts to invent, develop, and deploy new clean technologies will be inadequate because of additional market failures. In general, this calls for use of supplementary and targeted technology policies, rather than setting emissions control instruments more aggressively. Box 1.4 provides some discussion of the rationale for and type of technology policy.

[13] In fact, after the race to establish technology standards is over, the regulated community may actively move away from developing better technologies for fear of opening up new rule-making.

Box 1.4. The Potential Case for Complementary Technology Policies

Generally, economists recommend that technology-related market failures associated with basic research, applied research and development (R&D) at firms, and technology deployment require their own instruments. There are some general caveats to bear in mind, however:

- *Technology policies should be a complement to, not a substitute for, emissions mitigation policies.* As noted above, emissions pricing is the single most effective policy to reduce emissions (given current technology) and also stimulate clean technology investments.
- *In general, the playing field should not be tilted in favor of one specific technology over others.* So policies to subsidize carbon capture and storage or that mandate use of certain types of alternative-fuel vehicles rather than stimulating all comers could be inefficient unless the market failures are especially severe for the favored technologies.
- *Innovative activity in the public sector or the energy sector may "crowd out" such activity elsewhere in the economy.* For example, new scientists and engineers working on energy technologies might have previously worked in other sectors.

These factors suggest that technology policies need to be carefully scaled and designed. Which instrument is appropriate and how long it should be applied depend on the nature of the market failure. There are several possibilities for technology-related market failures, though some are less convincing than others.

There is a potentially strong case for policies encouraging basic research in publicly funded institutions and applied R&D at firms. In particular, the "public goods" problem—that is, the inability of innovators to capture spillover benefits to other potential users from technology breakthroughs—is most severe at this stage of the innovation process. Indeed, for the United States, numerous studies show that the social rate of return to basic R&D (i.e., including benefits to all potential users) is several times the private rate of return.[14] Although the problem applies to innovation in general, it can be more pronounced for clean energy technologies, given that many of them (e.g., renewable plants) have high upfront costs and long-range payoffs and that there is uncertainty regarding future governments' commitments to emissions pricing.

What Market Failures Might Justify Additional Support for Energy-Related Technologies?

Early producers of new technologies often invoke the "infant industry" argument that a fledgling sector needs protection from world markets, say through tariffs or nontariff

[14] Likewise, policies that encourage general education and training of innovators are desirable because any one employer who engages in such activities may see its employee leave for another job.

Box 1.4. (*continued*)

trade barriers. But this argument means little for economic efficiency in the country as a whole (and in the short term will reduce economic efficiency) and, if accepted, requires a strict criterion for judging when the industry has "grown up."

A potentially more solid case for technology policies arises if firms are reluctant to adopt new technologies because they would bear all the costs of "learning by doing," which benefits later users of the technology. This provides a possible rationale for clean technology deployment policies. But policies should be transitory and phased out as the technology matures. Moreover, gauging the future penetration rate of a new technology can be difficult given uncertainty over its costs and that of competing technologies, suggesting the desirability of a flexible pricing instrument (e.g., a subsidy) over a quantity instrument (e.g., a minimum sales share requirement for electric vehicles) that forces the new technology regardless of its costs. And there is a danger of creating an uneven playing field if some technologies are favored at the expense of others.

Another argument for technology deployment policies is that consumers' demand for energy-efficient investments is held back by their myopia—they seem unwilling to make a big investment today that will pay for itself in several years, rather than over the entire lifetime of the investment. For this argument to stand, we need to distinguish between "hidden" costs and market failure. If consumers are reluctant to buy because the technologies are unproven or the costs are hidden (e.g., reluctance to buy compact fluorescent lights reflects their perceived lower quality compared with incandescent light bulbs), this is not a justification for intervention.

On the other hand, consumers may lack information about the features and lifetime energy savings of particular technologies. Alternatively, the person making the purchase decision (e.g., a landlord) may not care about energy savings if these benefit someone else (a tenant responsible for paying energy bills). Furthermore, capital markets may unreasonably deny households access to credit to make large investment purchases. In principle, these market failures would justify some form of policy intervention such as information campaigns if the problem lies in that area, reform of tenant-landlord interactions, measures to increase credit availability, or incentives for clean technology adoption.

Finally, policies such as subsidies or prices that target the improvement of networks (e.g., new pipeline infrastructure for clean fuels) are also potentially warranted. In these cases, the benefits of the technologies to other firms may be so pervasive that no single private company can appropriate them all. Alternatively, the risk of the technology failing may be higher than a private concern can handle but may be acceptable to a government, which has more opportunities to hedge against such failure and has lower costs of accessing funds.

Source: Authors.

Conclusion

The choice of instruments to reduce CO_2 is a complex one. In this chapter, we have laid out the basics of a comparison of instruments according to five criteria, and the main points are summarized in matrix form in Table 1.1.

Market-based instruments are potentially the most effective policies for reducing emissions, although raising revenue and using that revenue productively are important for containing their overall policy costs. The choice between carbon taxes and cap-and-trade systems is less important than implementing one of them and getting the design details right, which include comprehensive coverage of emissions, exploiting the fiscal dividend, and (in trading systems) limiting price variability, although only carbon taxes may be viable if institutions for credit trading are lacking. If carbon pricing policies are not initially acceptable, a combination of regulatory policies can be a reasonable alternative for the time being if they are carefully chosen to mimic, insofar as possible, the emissions reduction opportunities that would be exploited under comprehensive pricing policies and they include extensive credit trading provisions. In the latter regard, using feebate alternatives to regulations is simpler as it avoids the need for institutions to enforce credit trading.

Table 1.1. Summary Comparison of Policy Instruments

Policy Instrument	Effectiveness at Reducing Economy-Wide CO_2	Cost-Effectiveness[a]	Dealing with Uncertainty over Abatement Costs[b]	Promoting Clean Technology Deployment	Incidence and Competitiveness	Overall Assessment
Comprehensive carbon taxes (upstream)	Most effective policy	Cost-effective[c]	Automatically accommodates uncertainty	Effective, though supplementary measures to overcome technology barriers may be needed	Energy price impact can burden low-income households and harm competitiveness	Potentially the best policy, but incidence and competitiveness effects may need addressing
Comprehensive cap-and-trade (upstream)	Same as comprehensive carbon tax	Cost-effective if allowances auctioned[c]	Price stability provisions needed	Same as comprehensive carbon tax (with price stability provisions)	Same as comprehensive carbon tax if allowances are auctioned (but incidence can change if allowances are freely allocated)	Same as comprehensive carbon tax (1) if allowances are auctioned, (2) there are price stability provisions, (3) there are well-functioning credit markets
Carbon tax with partial coverage (downstream)	Partially effective	Cost-effective[c]	Automatically accommodates uncertainty	Promotes narrower range of technology investments	Similar issues as under comprehensive carbon tax	Potentially attractive initially (in absence of comprehensive tax)
Cap-and-trade with partial coverage (downsteam)	Same as partial carbon tax	Cost-effective if allowances auctioned[c]	Price stability provisions needed	Same as partial carbon tax (with price stability provisions)	Same as partial carbon tax if allowances are auctioned (but incidence can change if allowances are freely allocated)	Same as partial carbon tax (1) if allowances are auctioned, (2) there are price stability provisions, (3) there are well-functioning credit markets
Pure electricity tax	Limited effectiveness	Cost-effective for small emissions reductions[c]	Automatically accommodates uncertainty	Promotes a very narrow range of clean technologies	Similar issues as under the comprehensive carbon tax	Generally not recommended (unless combined with other mitigation instruments)
Simple excise tax on vehicle purchases	Very ineffective	Cost-effective for very small emissions reductions[c]	Uncertainty is not an issue	There is essentially no effect	Imposes burden on motorists	Not recommended on environmental grounds

Taxes on individual fuels	Limited, though some taxes (on coal) are more effective than others (on gasoline)	Cost-effective for modest emissions reductions[c]	Automatically accommodates uncertainty	Promotes limited range of clean technologies	Some burden on households and firms	Inferior to comprehensive emissions pricing
Incentives for clean generation fuels	Limited effectiveness	Fairly cost-effective (for modest emissions reduction) if there are credit trading provisions for quantity instruments	Price instruments accommodate uncertainty, quantity instruments require price stability provisions	Promotes limited range of clean technologies	Fairly small burden on households and firms (for moderately scaled policy)	Inferior to comprehensive emissions pricing
Emissions standards (for power sector)	Fairly effective (for power sector)	Cost-effective if credit trading provisions	Price stability provisions needed	Provides little incentives for electricity-saving technologies or technologies in other sectors	Fairly small burden on households and firms (for moderately scaled policy)	Promising if comprehensive market-based policy is not feasible, but it should be combined with other policies
Energy efficiency standards	Limited effectiveness	Cost-effective (for modest emissions reduction) if credit trading across firms	Price stability provisions needed	Promotes only limited range of technology investments	Relatively modest burden on households and firms	Not a substitute for emissions pricing, but could play a useful role in regulatory combination
Feebates	Fairly effective (for power sector)	Cost-effective (for modest to partial emissions reductions)	Automatically accommodates uncertainty	Promotes some technology investments	Modest burden on households and firms	Promising in absence of comprehensive emissions pricing, but several schemes required for different sectors
Regulatory combination[d]	Potentially fairly effective	Fairly cost-effective if there is credit trading across firms and sectors	Price stability provisions needed	Promotes a fairly broad range of technology investments	Fairly modest burden on households and firms for moderately scaled policy	Promising in absence of comprehensive emissions pricing, if there is extensive credit trading across sectors

Source: Authors.
[a] Compares costs for the *different* level of emissions reductions achieved by different policies.
[b] Note the limited treatment of uncertainty in this column.
[c] Assumes revenues are used productively to improve economic efficiency, such as to reduce other distortionary taxes.
[d] Combining energy-efficiency standards for major products (e.g., vehicles, buildings, household appliances) with emissions standards for power generation.

References and Suggested Readings

For a general discussion comparing a broad range of alternative carbon mitigation instruments, see the following:

Aldy, Joseph E., and Robert N. Stavins, 2011, "Using the Market to Address Climate Change: Insights from Theory and Experience," Discussion paper RWP11-038 (Cambridge, Massachusetts: Harvard University Kennedy School of Government).

Goulder, Lawrence H., and Ian W. H. Parry, 2008, "Instrument Choice in Environmental Policy," *Review of Environmental Economics and Policy,* Vol. 2, pp. 152–174.

Krupnick, Alan J., Ian W. H. Parry, Margaret Walls, Tony Knowles, and Kristin Hayes, 2010, *Toward a New National Energy Policy: Assessing the Options* (Washington: Resources for the Future and National Energy Policy Institute).

General issues in the choice between carbon taxes and emissions trading systems are covered in the following:

Hepburn, Cameron, 2006, "Regulating by Prices, Quantities or Both: An Update and an Overview," *Oxford Review of Economic Policy,* Vol. 22, pp. 226–247.

Nordhaus William, 2007, "To Tax or Not to Tax: Alternative Approaches to Slowing Global Warming," *Review of Environmental Economics and Policy,* Vol. 1, pp. 26–44.

For a focus on the importance of revenue recycling for containing the costs of market-based policies, see the following:

Parry, Ian W. H., and Roberton C. Williams, 2012, "Moving US Climate Policy Forward: Are Carbon Tax Shifts the Only Good Alternative?" in *Climate Change and Common Sense: Essays in Honor of Tom Schelling*, ed. by Robert Hahn and Alistair Ulph (Oxford, UK: Oxford University Press, pp. 173–202).

For a discussion of possible manipulation in allowance trading markets, see the following:

Stocking, Andrew, 2010, "Unintended Consequences of Price Controls: An Application to Allowance Markets," Working Paper 2010–06 (Washington: Congressional Budget Office), September.

For some discussion of instruments for promoting clean fuels in power generation, see the following:

Aldy, Joseph E., 2011, "Promoting Clean Energy in the American Power Sector," Hamilton Project discussion paper 2011–04 (Washington: Brookings Institution).

Palmer, Karen, Richard Sweeney, and Maura Allaire, 2010, "Modeling Policies To Promote Renewable and Low-Carbon Sources of Electricity," Background paper for Krupnick, Alan J., Ian W. H. Parry, Margaret Walls, Tony Knowles, and Kristin Hayes, 2010, *Toward a New National Energy Policy: Assessing the Options* (Washington: Resources for the Future and National Energy Policy Institute).

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