ISSUE BRIEF 10

CLIMATE TECHNOLOGY DEPLOYMENT POLICY

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SUMMARY

There is a growing consensus among policymakers and stakeholders that an effective federal program to control greenhouse gas (GHG) emissions must have as one element polices to hasten the development and commercialization of low- and no-carbon energy technologies, as well as technologies that improve end-use energy efficiency. Alongside policies designed to directly mandate GHG reductions, such as a GHG cap-and-trade system, policies that instead target the development and adoption of GHG-reducing technologies have been much discussed. While both general types of policies may have GHG reductions as their ultimate aim, technology policies are often framed in terms of technology-development activities or technology-specific mandates and incentives rather than primarily in terms of emissions.

A wide range of climate-related technology policy options are currently being employed or have been proposed at the federal and state levels. It is useful to categorize these options roughly according to which stage of the technology-development process they target: research, development, and demonstration, or widespread commercial deployment. This issue brief focuses on technology deployment, while a companion brief (Issue Brief #9) addresses technology research, development, and demonstration, including options for funding, institutions, and research policy instruments.

After exploring various rationales and motivations for implementing technology-deployment policies as part of a strategy for addressing climate change, this paper examines relevant policy options, including standards (e.g., technology, performance, and efficiency standards), subsidies (e.g., tax credits, tendering, loan guarantees), and limited liability. A number of important messages emerge:

- Pricing GHG emissions through a cap-and-trade or tax system would provide direct, cost-effective, and technology-neutral financial incentives for the deployment of GHG-reducing technology.

- For technology policies to help achieve a given level of emissions reductions at lower overall social cost than an emissions-pricing policy alone, they must be targeted to addressing market problems *other than* emissions reduction per se. Thus technology policies are best viewed as a *complement to* rather than a *substitute for* an emissions pricing policy.

- As complements to a cap-and-trade system, technology policies will tend to lower the allowance price associated with achieving a given aggregate cap level, rather than producing additional emissions reductions below the cap. As complements to a GHG tax, such policies will tend to increase the total amount of emissions reductions achieved by a given tax. Again, because the emissions price may not be a complete measure of cost, whether technology policies lower the overall cost

to society of achieving emissions reductions depends on their being well-designed and targeted to addressing distinct market problems.

- There are several specific market problems to which technology deployment policies could be efficiently directed, if the benefits of practicable policies were found to justify the costs in particular circumstances. These market problems include information problems related to energy-efficiency investment decisions, knowledge spillovers from learning during deployment, asymmetric information between project developers and lenders, network effects in large integrated systems, and incomplete insurance markets for liability associated with specific technologies.

- Although market problems are often cited in justifying deployment policies, such policies in practice often go much further in promoting particular technologies than a response to a legitimate market problem would require. Therefore, while conceptually sound rationales may exist for implementing these policies, economists and others tend to be skeptical that many of them, as actually proposed and implemented, would provide a cost-effective addition to market-based policies. Critics point out that deployment policies intended to last only during the early stages of commercialization and deployment often create vested interests that make the policies difficult to end.

- Others argue that mandating GHG reductions will be more politically feasible if government includes policies tied to the deployment of specific technologies. These policies may attract more support than a pricing policy because they often employ "carrots" (subsidies) rather than "sticks" (fees or mandates), provide a way to promote particular technologies that have strong political constituencies (such as biofuels), make the cost of reducing emissions and adopting new technologies less visible by spreading it to the general taxpayer, and may not have an explicit price attached to them (as do emissions prices).

- Technology standards and subsidies can be viewed as different means to achieve the same ends (for example, increased energy efficiency, greater reliance on renewable energy). Just as there are important differences between an emissions-trading program and an emissions tax, however, standards and subsidies tend to differ in terms of who bears the cost, how their impact evolves over time, and what kinds of outcomes they guarantee (that is, whether they provide certainty about achieving certain deployment objectives versus certainty about achieving certain cost objectives).

- Standards tend to guarantee that specific technologies will be deployed in a certain quantity (or as a minimum share of the market) or that certain performance criteria will be achieved, but leave the cost of achieving the standards uncertain. Technology subsidies, on the other hand, pin the incremental cost spent on technology to the level of the incentive and leave uncertain how much deployment (or what level of performance) will be achieved at that cost. Ceilings (and floors) on credit prices within a tradable standards system can blur these distinctions.

- Regarding distributional consequences, the cost of imposing a standard tends to fall primarily on households and firms in the regulated sector. By contrast, the cost of providing subsidies tends to fall on taxpayers more generally. However, this distinction can also be altered somewhat through self-financing mechanisms such as "feebates" (to promote improved automobile fuel economy, for example, subsidies for efficient vehicles could be funded by fees on inefficient vehicles).

- Different deployment policies also have different dynamic properties. The incentives generated by standards are typically more static in the sense that industry has no reason to exceed the standard, which eventually becomes less binding as technology matures (of course, as technology improves, policymakers may also respond by raising standards). Fixed subsidy levels, on the other hand, may continue to provide incremental deployment incentives, depending on the payment structure.

- As with emission standards, the cost-effectiveness of technology-oriented standards can be increased by incorporating flexibility mechanisms such as credit trading, banking, and borrowing. Likewise, tendering, or reverse auctions, can help facilitate cost competition by making subsidy recipients bid for the minimum subsidy needed to deliver a specified quantity of new technology. This approach can help reduce the cost of technology deployment over time by ensuring that a given expenditure of public resources produces the maximum amount of deployment (or conversely, that a given deployment target is achieved at the lowest possible cost to taxpayers).

- Loan guarantee programs may be conceptually justified if informational asymmetries exist in credit markets for relevant technologies. On the other hand, loan guarantees create implicit subsidies; as such, their benefits must justify their costs. Because loan guarantees insulate projects, at least in part, from default risk, they can create incentives for developers to take on riskier projects while doing less than they should to guard against preventable risks.

- There may be a rationale for establishing a joint insurance pool or limiting liability for certain technologies like carbon storage if there is insufficient availability of private liability insurance or there are substantial potential difficulties in assigning liability. On the other hand, liability protection provides a form of implicit subsidy by insulating parties from potential damages caused by their technologies. Thus, if designed poorly they may reduce incentives for those parties to take appropriate actions to mitigate risks where possible.

- Finally, a number of other polices may be critical in helping certain GHG-reducing technologies compete effectively to potentially gain a foothold in the marketplace. The successful deployment of new technologies often requires better information and verification methods; infrastructure planning, permitting, compatibility standards, and other supporting regulatory developments; and institutional structures that facilitate technology transfer, such as rule of law, judicial or regulatory transparency, intellectual property protection, and open markets. A balance must be struck, however, between enabling technologies to compete and constructing policies that preferentially support specific technology options or systems.

The Role of Climate Technology Deployment Policies

When considered alongside policies that directly mandate GHG reductions, additional technology policies may not seem necessary or desirable. After all, the market-based approaches featured in most recent proposals for a mandatory U.S. climate policy would give rise to a price on GHG emissions. This price places a clear financial value on GHG reductions and like other market prices (such as energy prices) should induce households and firms to buy technologies with lower GHG emissions (for example, more energy-efficient products) the next time they are in the market.

Generic public funding for research tends to receive widespread support based on the significant positive spillovers that are often associated with the generation of new knowledge. Agreement about the appropriate role of public policy in technology development tends to weaken, however, as one moves from policies targeting research and development to policies directed at demonstration projects and particularly deployment. In the case of standard market goods, many experts (and especially economists) believe that while the government's role in supporting research may be clear, the rationale for government intervention quickly weakens when it comes to commercializing and deploying new technology on a large scale.

A similar point of view might carry over to the rationale for government intervention on behalf, specifically, of new technologies to reduce GHG emissions, *if* a sufficient market price has been placed on these emissions through government policy. This perspective would tend to support a complementary set of strategies that couple emissions pricing policies with policies to support research, development, and demonstration (where public investment in demonstration is limited and directed toward learning)—but *not* widespread deployment. There are nonetheless several economic rationales and other motivations for considering measures oriented toward technology deployment within a portfolio of climate policies.

Information problems provide one rationale for policies to promote energy-efficient technologies. This is particularly the case where it has been demonstrated that consumers systematically undervalue energy efficiency or where the incentives for efficiency investments are split between those who pay for a new technology and those who benefit. A good example is the landlord-tenant problem: a landlord has no incentive to pay for efficiency improvements if the tenant pays the energy bills and therefore captures any resulting cost savings. Another potential rationale involves spillover effects and the process of so-called "learning-by-doing"—a term that describes the tendency for production costs to fall as manufacturers gain production experience. An emissions price will encourage producers to make investments in new technology that result in learning-by-doing. But if the benefits of this learning spill over to other producers without full compensation to the early adopters, incentives for early adoption will be diluted and investment in learning-by-doing will fall short of what is optimal for society as a whole at a given emissions price. In cases like this, a compelling rationale may exist, in principle, for public support of deployment efforts early in the transition to commercialization.

Any deployment policy must strike a careful balance between enabling technologies to compete and preferentially supporting specific options or systems.

Network effects provide a motivation for deployment policies aimed at improving coordination and planning—and, where appropriate, developing compatibility standards—in situations that involve interrelated technologies, particularly within large integrated systems (for example, energy production, transmission, and distribution networks). Setting standards in a network context may reduce excess inertia (for example, so-called chicken-and-egg problems with alternative-fueled vehicles), while simultaneously reducing search and coordination costs, but standards can also reduce the diversity of technology options offered and may impede innovation over time. Loan guarantee programs may be conceptually justified if informational asymmetries exist in credit markets for relevant technologies. Finally, incomplete insurance markets may provide a rationale for liability protection or other policies for certain technology options (for example, long-term CO_2 storage).

The argument against technology-oriented policies, even where the market problems described above exist, centers on the concern that government is ill-positioned to "pick winners" among a broad array of technological possibilities and commercial opportunities. Critics argue that decisions about new technology are best left to a private sector motivated through broad incentives such as a price on GHGs. In this view, technology deployment policies represent an unnecessarily restrictive and costly strategy for advancing the larger policy objective, where that objective—in this case, reducing GHG emissions—can be less expensively achieved through flexible market-based policies. Another perspective is that even if it were theoretically possible to address the market problems noted above through deployment policies, the practical import of attempting to do so would likely be negligible and/or more than offset by the cost and waste associated with pork barrel spending and unnecessary government intrusion into the market. From this perspective, simply pointing to the conceptual plausibility that certain market imperfections exist is insufficient; rather, one would need to closely measure the extent of such problems in specific cases and tailor policy interventions accordingly. This would mean identifying practicable policies that directly address the problems identified—and then implementing those policies in a manner that ensures benefits exceed costs (and ideally that net benefits are maximized).

The remainder of this issue brief discusses several common types of technology deployment policies in more detail. A number of other polices and programs are not covered here, but may be critical in helping to enable certain GHG-reducing technologies to compete effectively, including:

- Information programs (such as product efficiency labeling or energy efficiency audits) and programs to develop measurement and verification methods (for example, for energy-efficiency technologies, carbon storage, etc.)
- Infrastructure planning; permitting; regulatory development; compatibility standards (for example, for fueling systems); and public outreach for specific technology options, systems, and networks (for example, transmission and distribution lines, nuclear waste storage, carbon capture and storage)
- Programs to promote international technology transfer and encourage the development of structures or institutions that enable technology transfer (such as rule of law, judicial or regulatory transparency, intellectual property protection, and open markets)

Before moving on to a detailed discussion of standards, subsidies, and liability protection as means for accelerating the commercialization of new technologies, it is worth emphasizing the general point that any deployment policy (including the additional types of policies noted above) must strike a careful balance between enabling technologies to compete and preferentially supporting specific options or systems.

Standards

Standards can take several forms and provide varying degrees of flexibility, from uniform technology standards at one end of the spectrum to fully tradable emissions standards at the other. The cost-effectiveness of these approaches tends to improve as one moves from rigid technology standards toward standards that can be implemented using a market-based trading system. This is because more flexible standards—applied to actual emissions—can be designed to take advantage of all major means of reducing emissions, including substitution toward more efficient equipment and lower-carbon fuel inputs, end-of-pipe emissions control (for example, carbon capture and storage), and changes in end-use demand.[1] The cost-effectiveness of any type of standard—technology-based or otherwise—can typically be increased by incorporating flexibility through credit trading, banking, and borrowing. Cost certainty can be introduced by incorporating price ceilings (and floors) for compliance credits, as in an emissions cap-and-trade system.

Uniform Technology Standards

The least flexible type of regulation is a uniform technology standard that requires every covered entity to install a particular type of technology. Examples include requirements that all coal-fired power plants install carbon capture and storage technology, that all light bulbs be fluorescent, or that all vehicles be flex-fuel capable. Technology standards of this type each take advantage of only one means of reducing emissions.

In response to this critique, one might attempt to establish a suite of technology standards that cover every aspect of the system in question and thereby attempt to capture all abatement opportunities. But to produce cost-effective results, this approach would require setting each individual technology requirement in a way that equalized incremental emissions abatement costs across the system as a whole. Even if it were practically possible to do this for an individual facility or firm, it would be impossible to set a single set of standards that balanced the various circumstances at *each* individual firm or facility in a manner that minimized total costs. Uniform technology standards may also stifle innovation over time because once the standard is achieved there is no incentive to go beyond it (other than to reduce the cost of the approved technology). A primary advantage of uniform technology standards, on the other hand, is that verifying the installation and operation of required technologies is relatively easy. This advantage from an enforcement standpoint is unlikely to be important in an advanced industrialized country like the United States, but may be more relevant in certain developing country contexts.

Market Share (Portfolio) Standards

Market share or "portfolio" standards provide additional flexibility by applying requirements at an industry-wide level, rather than obliging every firm or facility to meet exactly the same technology standard. An example is a renewable portfolio standard designed to require that a minimum share of all electricity sold in a state comes from qualifying renewable sources. If one firm faces relatively high costs in delivering renewably generated power, it can buy renewable energy credits from a firm that faces lower costs, just as in an emissions cap-and-trade system. Renewable portfolio standards have been adopted by over 20 states and proposed at the federal level. In states that have such standards, different technologies qualify toward meeting the standard; in addition, some states have separate targets for specific types of renewable technology (e.g., solar).

The portfolio standard concept has also been proposed for other types of climate-friendly technologies and even for end-use efficiency. For example, a portfolio standard to promote carbon capture and storage could require that a certain number or share of all new fossil-fueled power plants be fitted with carbon capture and storage technology. Alternatively, a broader clean energy portfolio standard could be designed to include all non-carbon forms of power generation, including nuclear power in addition to renewables and fossil systems with carbon capture and storage. Similarly, some states have begun to experiment with "efficiency portfolio standards" that require utilities to meet a minimum percentage of demand for electricity services through energy efficiency programs (the same idea has also been proposed at the federal level).[2]

The design of such standards will obviously have a large impact on their cost-effectiveness. As a means of reducing GHG emissions, for example, a portfolio standard that includes more low-carbon options will tend to reduce costs relative to a portfolio standard that is focused on a particular type of technology.

Emissions Performance Standards

Emissions performance standards specify a certain maximum level of emissions per unit of output (for example, pounds of CO_2 per kWh or grams of CO_2 per gallon of motor fuel). Performance standards can also be imposed at the level of an individual source or, if trading is allowed, at the level of an

1 Applying flexible performance standards to equipment *manufacturers*, versus to direct emitters, does not have these properties. Flexibility in meeting an equipment efficiency standard may lower compliance costs for equipment manufacturers, but will not, for example, encourage reductions in end-use energy demand.

2 See further discussion in Issue Brief #11, which provides more detail on issues related to climate-change regulation in the electricity sector.

industry or sector as a whole (in which case the standard will give rise to a tradable emissions credit system). Performance standards reflect a desire to move away from specifying particular technologies or classes of technology, toward a focus on regulating emissions in a technology-neutral fashion. This tendency is evident in the increasingly broad types of portfolio standards described above, with a "clean energy" portfolio standard being the broadest. From the standpoint of reducing emissions it might also make sense to encourage relatively low-emission conventional coal and natural gas systems, as well as more efficient electricity production and end-use technologies, in addition to the technologies typically included in renewable or clean energy portfolio standards.

The desire to encourage a wide variety of abatement options leads logically back to a broad policy approach: tradable emissions performance standards or even an emissions cap-and-trade system. The primary distinction between a tradable emissions performance standard and a cap-and-trade system is that the performance standard is intensity-based. That means the overall quantity of emissions allowed under the system will vary depending on the level of output (in other words, if a GHG performance standard, in pounds per kWh, is applied to electricity production, then final emissions will depend on how many kWh are generated). A drawback of intensity-based standards (relative to a quantity-based cap-and-trade program) is that they create an implicit subsidy to increase output: as firms produce more, they are allowed a greater quantity of emissions. Any additional emissions that result from an increase in production, up to the level of the performance standard, are free to the producer. This means, in effect, that firms have the ability to generate the equivalent of free allowances by increasing their output. As a result, achieving an equivalent emissions target using intensity-based performance standards will tend to result in higher emissions prices and lower output prices relative to achieving the same target using a cap-and-trade system. The overall cost of attaining a given emissions target will also tend to be higher because the performance standard, by keeping output prices relatively low, does not encourage as much end-use energy efficiency and conservation.

On the other hand, the implicit allocation of credits based on output can protect consumers from bearing the cost of emissions allowances passed on to them by firms that might otherwise experience a windfall gain if they receive free allowances under a cap-and-trade program. The implicit allocation of emission credits to regulated entities under a tradable performance standard therefore produces different distributional effects relative to a cap-and-trade system, where the decision about how to allocate allowances can be separated from the decision about which entities get regulated.

> The cost-effectiveness of any type of standard—technology-based or otherwise—can typically be increased by incorporating flexibility through credit trading, banking, and borrowing.

Another distinction between these two approaches is that performance standards must be applied at the sector or sub-sector level, where the unit of output is comparable. Unless sector-specific performance standards are linked through inter-sector emissions trading, this can lead to differences in the stringency of the standards applied to different sectors and to unnecessarily costly emissions reductions overall. This need to develop different output metrics and emissions targets for different sectors is in contrast to a cap-and-trade system where the only relevant units are tons of emissions and where the system can apply on an economy-wide scale. Nonetheless, tradable performance standards hold some political appeal because they tend to keep output prices lower than under a cap-and-trade system, because they deal with credit allocation implicitly rather than explicitly, and because they tend to push regulatory decisions toward the sector level where they can be more readily managed by organized interests.

Energy Efficiency Standards

In contrast to emissions performance standards, energy efficiency standards regulate energy use—rather than emissions generated—per unit of output. In the United States, energy efficiency standards for equipment used in buildings have historically been applied in the form of minimum efficiencies for individual products (for example, refrigerators, air conditioners), while efficiency standards for automobiles have been applied in the form of fuel-economy standards averaged across manufacturers' fleets (where standards have to be met separately for each automobile company's domestic-car, imported-car, and light-truck fleet).

A number of recent proposals, however, have called for reforming the corporate average fuel economy or CAFE system to make it more flexible while simultaneously making the overall program more stringent. Specifically, recent proposals would allow CAFE compliance credits to be traded across fleets and across manufacturers. Similarly, as has already been noted, there is interest in "energy efficiency portfolio standards" that would target aggregate reductions in electricity use, rather than the efficiency levels of specific products. In the latter case, quantifying and verifying electricity savings (relative to what would have otherwise occurred) is more challenging than measuring renewable energy output, emissions, or the energy-efficiency of individual technologies. This presents a significant hurdle to the implementation of an efficiency portfolio standard that has the same simplicity and credibility as trading programs based on more readily measured metrics or characteristics. Nonetheless, some states have developed methods for measuring demand reductions and are beginning to include energy savings from conservation programs along with renewable energy in their portfolio standards.

As discussed earlier, the primary economic rationale for including energy efficiency standards in a suite of climate technology deployment policies is if there are verifiable market problems that result in sub-optimal purchasing decisions regarding the energy-related operating costs of vehicles and equipment. Such a rationale would continue to exist even with a CO_2 pricing policy, as any market problems that resulted in the undervaluation of future energy savings would also act to diminish the full impact of the emissions price in terms of creating incentives for energy-efficiency improvements. The relevant economic question then becomes how to set the stringency of the energy-efficiency policy so as to maximize its net benefits, taking into account all relevant costs and benefits. Analysts differ in their assessments concerning the extent to which consumers and firms really undervalue energy efficiency when making purchase decisions about energy-using equipment—indeed, this debate has persisted since the 1970s. Efforts to improve methods for measuring and verifying the effectiveness of energy-efficiency programs also continue and are receiving increased scrutiny as the expectations for these programs grow.

Subsidies

Mechanisms for subsidizing climate-friendly technologies come in a wide variety of forms, including tax credits, direct payments, tendering or reverse auctions, and loan guarantees. In the context of an emissions trading program, it is also possible to subsidize certain technologies through differentiated allowance allocation.[3] The common feature of these approaches is that they provide a positive financial incentive for purchasing and/or using particular technologies. Subsidies can be designed to reach the same ends as standards, but they operate by providing financial "carrots" rather than a regulatory or financial "sticks." This feature can have distinct political advantages compared to standards and market-based emissions policies, although it is worth noting that standards may hold greater appeal for technology *suppliers* because they provide a more guaranteed market. For example, increased renewable electricity generation can be pursued through either a production tax credit or a renewable portfolio standard (in fact, both are being used in the United States today in the sense that many states have introduced renewable portfolio standards on top of an existing federal production tax credit for renewable energy sources). Increased ethanol production can be induced through an excise tax credit or a renewable motor fuel standard (again, both are currently being used in the United States). Of course, a market-based policy that puts a price on emissions also provides positive financial incentives for the adoption of GHG-reducing technology—and does so in a technology-neutral fashion.

As means to achieving a particular technology end, however, there are several important differences between subsidies and standards. First, subsidies can guarantee a lower and upper limit to the amount of resources spent on technology deployment—either on an incremental basis, by setting the level of subsidy provided per unit of output (e.g., cents per kWh), and/or in aggregate by capping the total subsidy amount made available (total $). A price guarantee is often mentioned by renewable electricity developers as a positive feature of policies such as "feed-in tariffs," which guarantee a minimum price for renewable electricity delivered to the grid (Germany's system being an example). But subsidies do not guarantee that a particular technology-deployment target will

3 For example, the bill introduced by Senators Bingaman and Specter in the 110th Congress (S. 1766) provides "bonus" allowances for carbon capture and sequestration. In the European Union's Emissions Trading Scheme, different allocation rules for new facilities subsidize different technologies, though not always in a way that produces climate-friendly results.

be met—they may produce results that under- or over-shoot a particular target. Standards, on the other hand, can guarantee a particular level of performance in an individual technology or an aggregate penetration level or market share, but their ultimate cost is not known in advance. Including a price ceiling in the design of a tradable standard can blur this distinction, just as including a "safety valve" mechanism may blur the distinction between an emissions tax and a cap-and-trade system.

Second, subsidies require explicit or implicit (in the case of tax credits) financial outlays from the public treasury. By contrast, the cost of standards is born by producers and consumers within the regulated sector. This may be viewed as positive or negative depending on one's view of whether the broad beneficiaries of reduced climate risks (taxpayers) should pay for emissions reductions, or rather that the cost burden should fall on a narrower group of sources and consumers who impose those climate risks through their emissions. Alternatively, the difficulty of raising public funds might be seen as an argument in favor of standards. A third related difference is that subsidies drive the prices of outputs like electricity and motor fuel lower, which removes incentives for demand reductions and in fact encourages increased demand for, and supply of, energy services. This is a fundamental distinction and it leads most economists to the view that negative externalities, such as GHG emissions, are best addressed through policies that raise the cost of behaviors that produce those externalities while positive externalities—such as the spillover benefits and knowledge creation associated with research and development—are better addressed through policies that provide positive incentives. As discussed previously, however, variations of this general principle may be justified if technology subsidy policies are in fact designed to act as complements to an emissions policy in order to generate positive knowledge spillovers through learning and cost reduction for new technologies.[4] This implies that subsidy policies should only target technologies for which clear learning opportunities exist and should do so only in a limited fashion early in the deployment process. It should also be the case that subsidies elicit investment and produce learning that would not otherwise be undertaken by the private sector in response to the emissions policy alone. These criteria would likely *not* be met by a number of existing subsidies or mandates, many of which target relatively mature technologies (e.g., wind power, corn-based ethanol) where markets are well-established and significant early learning has already been achieved.

4 For example, when one company builds and operates a carbon capture and storage facility, it learns ways to implement this technology more cheaply. This knowledge is directly or indirectly shared with (that is, it spills over to) other companies as they build other facilities.

Finally, subsidies often require relatively large outlays of funding (or equivalently, they forego large amounts of revenue that would otherwise be collected by the public treasury) for the amount of incremental technology deployment they induce. This occurs because, under many subsidy designs, the subsidy accrues to parties that would have adopted the technology even absent the subsidy. So-called "free-riding" behavior—which studies have found can be quite high—will dilute the effectiveness of the policy in the sense that it reduces the actual environmental benefit achieved for a given expenditure of public resources. Some subsidy designs, such as tendering (reverse auctions) and loan guarantees, can be structured to better target truly incremental technology investment. Different types of subsidies also differ in terms of how they affect the budget (e.g., tax credits versus direct appropriations), and in terms of who is eligible or in a position to benefit (e.g., private companies who pay taxes versus public cooperatives that do not). The remainder of this section discusses the design and potential role of specific types of subsidy policies, including tax credits, tendering, and loan guarantees.

Tax Credits and Grants

Tax credits are often given to offset corporate income, personal income, sales, and property taxes as a form of technology subsidy. Tax credits can directly lower the up-front investment cost of new equipment; alternatively tax credits can be used to subsidize actual production using new equipment. Examples include the existing, federal renewable-energy production tax credit and similar, recently enacted tax credits for investments in new nuclear power generation and energy-efficient building equipment. Each type of tax credit has advantages and disadvantages in terms of how effectively it promotes technology deployment and makes use of limited resources. A generic disadvantage of tax credits is that they are ineffective if the relevant party has no taxable income (unless the tax credit is refundable), as may be the case for some start-up companies and certainly is the case for municipal and cooperative utilities that have no tax liability. In addition, the effectiveness of the credit is dependent on the larger tax code under which the credit is being granted.

Investment tax credits can be quite effective in promoting technology deployment because the entire incentive is provided up-front. Grants or direct investment subsidies likewise share this property; moreover, like investment tax credits, which typically cover only a portion of the investment, they can be designed to encourage or require cost-sharing. Grants have the advantage that they can be effective with entities that do not have taxable income; in addition, there is no lag between the time when the recipient has to put up funds for a project and the time when the subsidy benefit accrues. On the other hand, investment tax credits and grants provide no guarantee that the projects or technologies they subsidize will actually be used in the manner and to the extent needed to justify the investment. In addition, investment tax credits can encourage project developers to focus on inflating cost estimates (so as to maximize tax benefits) rather than on efficient production. Addressing this concern may require costly project monitoring.

Tax credits based on production, rather than investment, help to ensure that public resources go only to technologies that are actually used (an example is the current federal renewable-energy production tax credit, which is based on kWh generated rather than on investment in renewable energy projects). The disadvantage of production incentives is that they may be less effective at overcoming deployment hurdles in cases where up-front capital requirements present a significant challenge for new technologies. Given that there is often a significant lag between the initial financing of a project and actual production, and given that the availability of tax credits in future years may be subject to Congressional appropriations, firms may not be able to capitalize expected tax savings at the time the investment is made. Finally, production tax credits do little to address construction risk—that is, the possibility that a project, especially if it involves unfamiliar or groundbreaking technology, will never be successfully completed and produce useful output.

Tendering Policies (Reverse Auctions)

Tendering refers to a policy in which project developers submit proposals for new facilities and bid the minimum price they would accept for output. A government agency or authorized agent manages the reverse auction, accepting the lowest bids (hence the term 'reverse auction'). This approach forces would-be subsidy recipients to compete on the basis of cost. It has the advantage of maximizing the amount of deployment achieved for a given expenditure of public resources (or alternatively, of minimizing taxpayer outlays for a given amount of deployment) and can help reduce the cost of technology deployment over time.

For example, the United Kingdom established the Non-Fossil Fuel Obligation, a sequence of tendering auctions, between 1990 and 1999. During the course of the program the average price paid for electricity from large wind power projects reportedly fell by 75 percent, although other factors clearly contributed to this decline as well. From 1998 to 2001, the state of California held three reverse auctions for renewable energy. The Department of Defense, the U.S. Postal Service, and several other states have also used reverse auctions to significantly reduce government costs for certain purchases. Reverse auctions are likely to be most efficient for high-dollar, large-quantity, clearly-defined purchases where there are multiple potential suppliers.

> The economic rationale for technology deployment policies rests on society's interest in promoting complementary knowledge creation and dissemination—especially where new knowledge is critical to lower the cost of future emissions reductions.

Another concern that has been raised about reverse auctions, and indeed about technology deployment policies more generally, is that they tend to support whatever qualifying technology is currently least expensive, rather than technologies that might have greater potential in terms of the performance improvements and cost reductions that could be achieved through learning-by-doing. From this perspective, it makes sense to target deployment policies intended to promote learning-by-doing to a relatively narrow set of technologies where the potential for knowledge gains and related spillovers is highest. The rationale for narrowly targeting deployment policies may seem at odds with the notion that the broadest possible program coverage—in the context of an emissions pricing policy—will yield the least expensive reductions. In fact, the same arguments for broad coverage would apply to technology deployment policies if their primary purpose was to produce near-term emissions reductions.
As discussed earlier, however, the economic rationale for

technology deployment policies rests on society's interest in promoting complementary knowledge creation and dissemination—especially where new knowledge is critical to lower the cost of future emissions reductions. Thus, technology deployment policies should not be considered a substitute for cost-effective emissions policy and different design considerations should apply. As discussed previously, yet a different rationale applies in the case of deployment policies targeted specifically to energy-efficiency technologies: for the most part these policies, rather than being designed to generate new knowledge, serve a distinct informational purpose in terms of addressing market problems that affect energy operating-cost decisions.

A different concern is that a reverse auction system may favor incumbents who can submit lower bids due to size and experience. While low bids are an otherwise good thing, a competitive market is necessary for truly competitive bidding and it would be important to ensure that the market is indeed not captured by a small number of companies. Another issue that can arise is that many winning projects may go undeveloped, which can be a concern when the subsidy is delivered via investment tax credits that are pre-assigned due to credit caps (as they typically are).

Tendering auctions can be designed to address many of these concerns and could be legislated with the flexibility to adapt over time based on the results of previous auctions and ongoing technological developments. Among other things, a reverse auction can be subject to mandatory quantity levels and bid ceilings that might change subject to lessons learned in the previous round. Mechanisms can be incorporated in the way the auction is structured to prevent speculative bids; examples include requiring bidders to obtain prior planning permission or requiring winners to apply for relevant permits within a short period of time or lose the bid. The costs associated with these requirements may deter false bids, but may also create a trade off in terms of raising additional barriers to entry in the competition.

Loan Guarantees

In a loan guarantee program, the government takes responsibility for a certain portion of a loan in case the debtor defaults. Such programs may be conceptually justified if informational asymmetries exist in credit markets for relevant technologies. Technologies that are on the cusp of commercial viability—even if they appear very promising—may not be able to get loans at appropriate rates in private credit markets, either because they seem likely to default or because potential lenders simply lack the information needed to assess default risk. By vouching for these perceived "high-risk" projects, the government can give project developers access to lower-cost capital and thereby facilitate the early deployment of new technologies. Loan guarantees represent an implicit subsidy, however, and as with all other types of subsidies it is important that their benefits justify their costs. Because such guarantees insulate projects, at least in part, from default risk, they may create incentives for developers to take on riskier projects and do less than they should to protect against preventable risks.

Loan guarantee programs have been used extensively in the past for various social purposes, and their role in the energy- and climate-policy arena was recently expanded by the Energy Policy Act of 2005, which established a new loan guarantee program for clean energy technologies. Loan guarantees may be of more use to independent power producers and start-ups, as most investor-owned utilities have strong credit. Similarly, public and co-op utilities probably would not benefit from such guarantees since they generally borrow at rates that are already at or below the Treasury bond rate.

There has been some prior experience with the use of loan guarantees to encourage the commercialization of energy technologies. In the late 1970s, the U.S. Department of Energy (DOE) underwrote loan guarantees of up to 75 percent of debt financing for start-up plants to produce synthetic fuel. Under that program, DOE guaranteed $1.5 billion of the $2.2 billion Great Plains Coal Gasification Facility; after completion, the owners defaulted on the loan and abandoned the plant to DOE. The new owner, Dakota Gasification Company, now operates the plant at a net profit and some of the revenues are going to paying off DOE's original investment.

DOE has also provided loan guarantees for up to 90 percent of project debt financing and up to 90 percent of total costs for alcohol-fuel production facilities. In this case, DOE issued three loan guarantees for the construction of ethanol plants. One of the recipients, the New Energy Company, defaulted on its loan and DOE paid out the guarantee. After much refinancing, the company has become a major ethanol producer in the Midwest. Plant developers in two other instances also defaulted, but without a silver lining; one plant was sold for salvage and the other was dismantled and reconfigured. Another DOE loan guarantee program, for geothermal power, underwrote debt up to 75 percent of total project costs. Of eight projects, four defaulted. However, one developer used the DOE guarantee to build a successful geothermal-powered electric generation plant. After paying off its loan, the project developer used the experience to get private financing for several other facilities in California, eventually expanding to other states and abroad.

As this record suggests, the results of loan guarantee programs for energy technologies have been mixed, with many projects eventually defaulting on their loans and triggering a government payout. However, some recipients have leveraged the experience gained through projects backed by loan guarantees to establish a successful position in the energy sector. In any event, given the historic default rate it seems clear that these were not simply cases of asymmetric information, where private lenders didn't understand the technology or misperceived project risk. These projects really were high-risk, as evidenced by the fact that many of them ultimately defaulted.

In this context, questions have been raised concerning the implementation of "no-cost" loan guarantees for clean energy technologies currently under development at DOE, where the implicit credit subsidy provided by the guarantee is to be paid to DOE by the borrower at the time of the loan. It will be a challenge to determine the appropriate level of this payment if the government truly expects to bear no cost from guaranteeing the loan. Based on past experience, the cost of the credit subsidy may be substantial, which would imply that the borrower's upfront payment to DOE would also need to be substantial. If set too high, however, this payment might negate the appeal of the guarantee. In principle, an accurately set credit subsidy payment sets the loan guarantee at the appropriate level by solving the problem of asymmetric information (i.e., borrowers are in a better position to assess the risk of a specific project than lenders) rather than acting as an implicit subsidy. If the credit subsidy is paid for by appropriations from public funds, however, the loan guarantee becomes another form of subsidy. Even then, loan guarantees may represent an attractive *alternative* to other types of subsidies because they provide a useful screening mechanism for focusing subsidies on marginal projects and thereby mitigate, at least to some extent, the subsidy "free-rider" problem. In other words, this form of subsidy only costs the government money if a project defaults, in which case the project was probably sufficiently risky that it would not have gone forward without the additional incentive provided by loan guarantees.

Limited Liability

Due to the prevalence of coal in electricity generation, a major focus of recent climate-policy discussions has been overcoming hurdles to the commercialization of carbon capture and storage (CCS) technology. CCS entails capturing carbon released during energy production and sequestering it underground. Since the effects of a large accidental release of sequestered CO_2 would undo the GHG benefits of the technology—and could potentially create additional risks to human health or the environment[5]—the liability involved in early CCS projects could discourage investment in related technologies. By capping either the magnitude of damages or the timeframe over which a CCS project operator is liable for such risks, the government could alleviate a potentially major impediment to commercializing CCS technology. The economic rationale for a government role in establishing a joint insurance pool or limiting liability is strongest if insufficient private liability insurance is available or if there are substantial difficulties in assigning liability. The latter issue is particularly significant given the decadal to century-long timeframes relevant for CO_2 storage and given the potential for sequestered CO_2 to migrate through very large, interconnected underground reservoirs. On the other hand, liability protection provides a form of implicit subsidy by insulating parties from potential damages caused by their actions; as such, it may reduce incentives for those parties to take appropriate steps to mitigate risks where possible.

Previous Experience with Liability Caps

The federal government has established several liability caps in the past. The Price-Anderson Nuclear Industries Indemnity Act limits the liability of nuclear generation facilities. Reactor licensees are required to purchase the maximum amount of private insurance available ($300 million). Each licensee must also be prepared to contribute up to $95.8 million to an industry insurance pool in the case of an accident. Beyond these limits, there is no further private liability. The Montreal Convention limits the liability of airlines for damages incurred by passengers on international flights. The Oil Pollution Act (OPA), which applies to oil spills on water, limits liability based on the type and tonnage of a vessel. The OPA also governs the Oil Spill Liability Trust Fund, which is funded by a 5 cent-per-barrel tax on oil. The fund is capped at $2.7 billion and may be drawn upon if a responsible party can absolve itself of charges of negligence and legal violations.

5 A significant accidental release of CO_2 has the potential to acidify soil or water, or even—under circumstances where the gas is trapped in an enclosed space—to suffocate animals and people.

The Terrorism Risk Insurance Act establishes protocols for government assistance in the case of a major terror incident. The Act is triggered in cases where losses exceed $100 million. First, individual insurers must pay an amount up to 20 percent of their total earned premiums. After that threshold is passed, the federal government covers 85 percent of remaining damages. If damages to an industry are less than $27.5 billion, however, the assistance must be recouped from individual insurers as a surcharge on all commercial insurance premiums. There is an overall cap of $100 billion on total annual federal assistance.

Addressing Liability Issues for Carbon Storage

In addressing liability issues related to carbon storage, concerns about the potential climate impacts of CO_2 leakage back to the atmosphere should be treated separately from concerns about the potential for human health and local environmental damages in the event of a large-scale release. In addition, it will be important for liability policies to be clear in terms of which components of the storage system (e.g., transmission, injection, storage) they cover and when they start and over what time periods they apply (e.g., immediately upon project completion, after an initial period once capture and storage are underway, etc.).

In the case of carbon storage, the great diversity of possible sequestration sites makes estimating potential risks and damages difficult. Whereas the other liability funds discussed above were based on at least some actuarial data, little data exist for CCS technology and it is not clear that related practices—such as enhanced oil recovery—are sufficiently similar to provide reliable projections about the likely performance of large-scale CCS projects. Still, a small surcharge on carbon storage or other related activity is one option for supporting a CCS liability fund similar to the Oil Spill Liability Trust Fund. Another option for addressing climate-related liability concerns (as opposed to health and local environmental concerns) is to apply a small discount factor to carbon storage credits (if the potential for leakage is judged to be non-negligible); another is for the government—after some period of time—to assume any regulatory liability should such leakage occur.

The FutureGen initiative, which aims to have a working power plant with CCS operating by 2012, has already generated some activity in terms of liability policy. The final four potential sites for this initiative are in Texas and Illinois, and Texas has agreed to accept full liability for the project should it be located there. Illinois initially balked at offering liability protection, but has now adopted similar liability protections. It remains to be seen whether other states would accept this responsibility, or whether it will be adopted at a federal level. A potential downside is that federal liability protection could have the effect of associating CCS with nuclear power (which has a similar liability cap) and influencing perceptions about the potential for catastrophic damages. However, experts on carbon storage point out that the risk profile for CCS technology is fundamentally different from that of nuclear technology. Carbon storage appears likely to become safer (less prone to leakage) over time as the CO_2 is dissolved or trapped in surrounding water or porous rock. The risks associated with storing nuclear waste, on the other hand, arguably increase over time in the sense that the potential for leakage may be higher in the future than it is in the present (although the consequences of such leakage also become less severe over time as the waste decays and its radioactivity declines).