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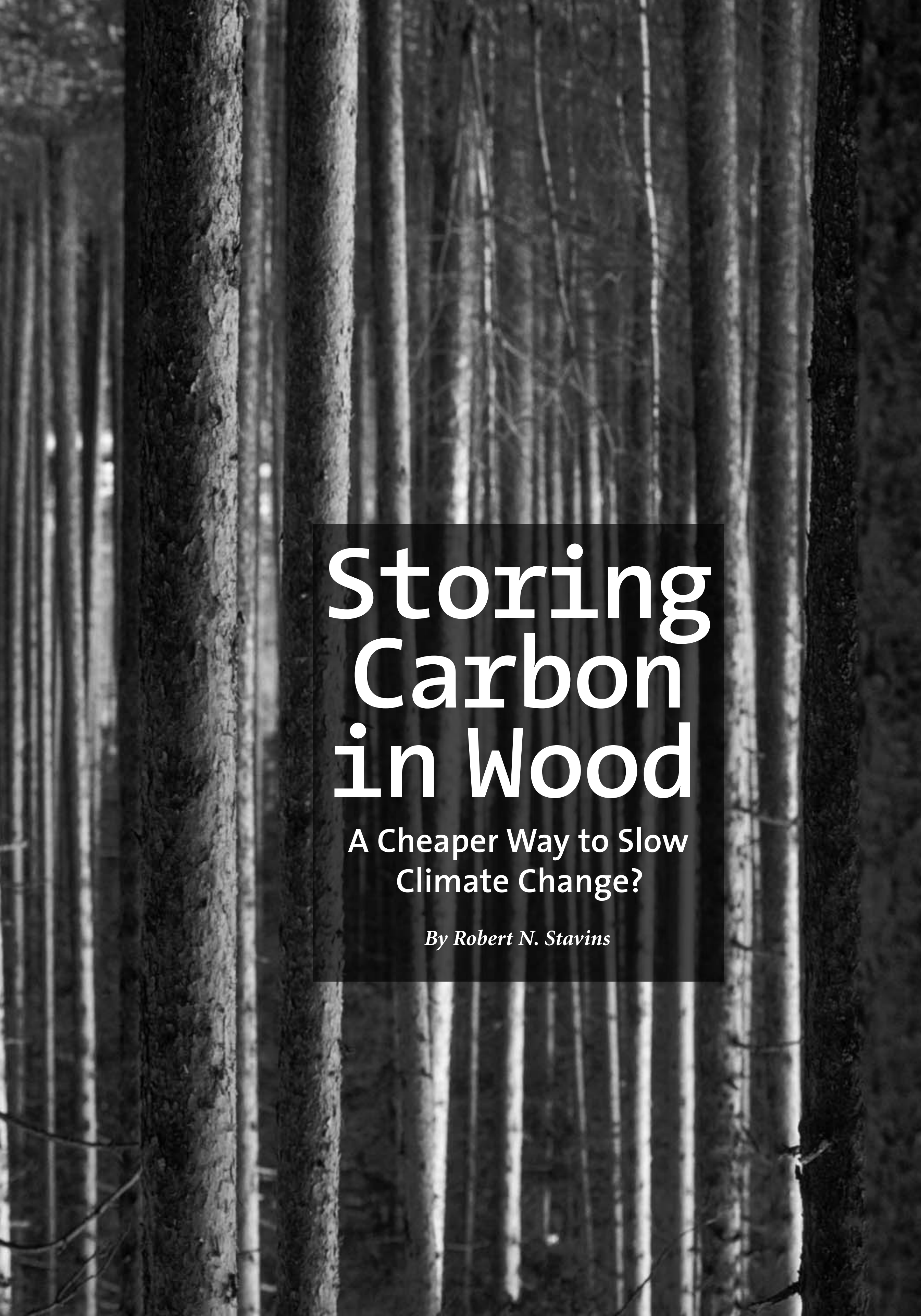

Storing Carbon in Wood

A Cheaper Way to Slow Climate Change?

By Robert N. Stavins

STORING CARBON IN WOOD

The straightforward way to slow climate change is to reduce the quantity of greenhouse gases (in particular, carbon dioxide) dumped into the atmosphere, giving the planet more time to recycle the offending chemicals. But in light of our late start, chances are we're going to need all the help we can get to prevent brutal changes in weather, widespread coastal flooding and perhaps even the spread of diseases now confined to the tropics. Hence the logic in giving nature a helping hand in sequestering atmospheric carbon.

Such storage, using technology ranging from very old to still-on-the-drawing-board, is certainly possible. The big question is how much carbon could be removed, at what cost. But I get ahead of myself. First, a brief refresher on how we got into this pickle and the options for repairing the damage.

OVERLOADING MOTHER EARTH

The earth's atmosphere contains carbon dioxide (CO2) and other "greenhouse" gases (GHGs) that reduce the rate at which solar energy is radiated back into space, thereby making the planet warmer than it would otherwise be. This greenhouse effect is crucial in keeping the planet habitable. If there were much less CO2 in the atmosphere, global temperatures would drop below levels at which ecosystems – and human civilization – could easily adapt. On the other hand, we have become all too aware that rising levels of greenhouse gases mean rising average temperatures, and the resulting potential for major ecological disruption.

Emissions are not a one-way street. The concentration of CO2 in the atmosphere is determined by a continuous recycling of carbon between the atmosphere, the ocean, the earth's biological systems and rock. As long as the amounts of carbon flowing into the atmosphere (as CO2) and out (in the form of plant material and carbon salts dissolved in the oceans or layered in rock) are in balance, the level of carbon in the atmosphere remains constant.

The complex natural mechanisms that sustain this equilibrium aren't perfect – CO2 concentrations (and the earth's weather) have changed gradually but radically. However, human activity – particularly the depletion of forests and the rapid combustion of carbon stored as fossil fuels that had accumulated over hundreds of millions of years – is causing the level of GHGs (primarily CO2) in the atmosphere to rise sharply in a matter of decades.

Burning coal, oil and natural gas contributes approximately 5.5 billion metric tons of carbon annually, while land-use changes account for another 1.1 billion tons. On the other side of the equation, the oceans are absorbing approximately two billion more tons of carbon than they release each year, while the earth's ecosystems are accumulating another 1.2 billion tons. All in all, then, roughly 3.4 billion tons of carbon are being added to the atmosphere annually.

That annual increase in atmospheric carbon may seem modest compared with the 750 billion tons already there, but it is adding up rapidly. If the current rate of atmospheric carbon accumulation were to remain constant, there would be a net gain in carbon levels of 25 percent over the next half century.

In fact, the rate at which human activity contributes to increases in atmospheric carbon is not constant – it's accelerating. The primary culprit has been, of course, the growth worldwide in the use of fossil fuels to

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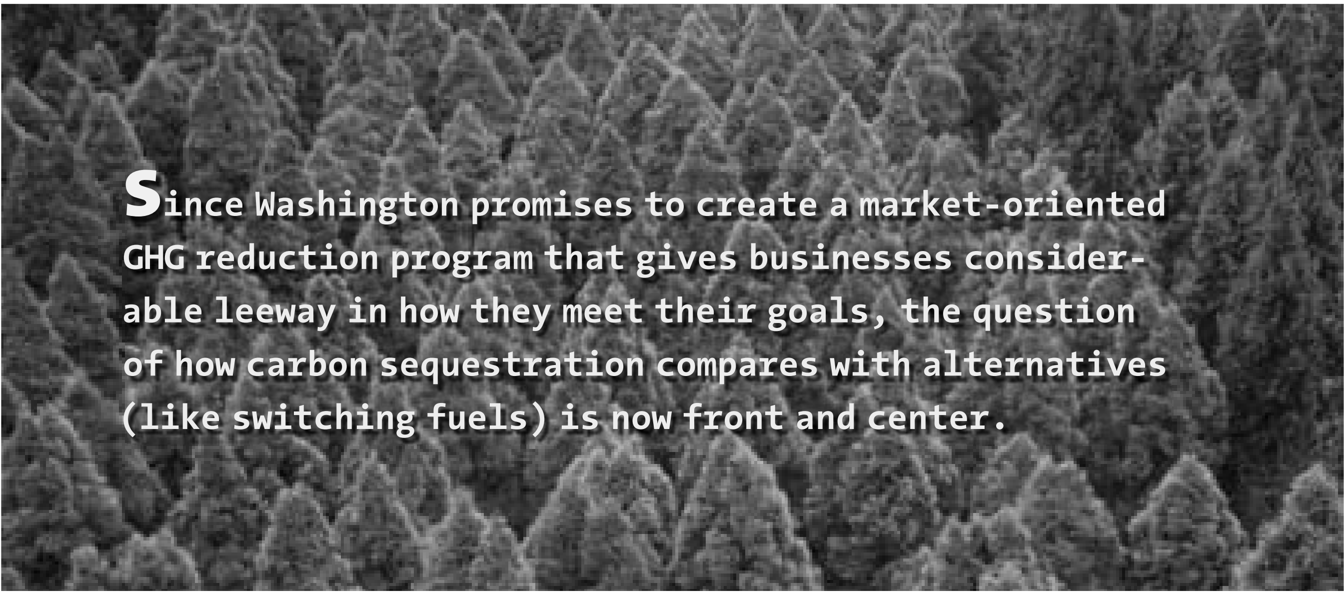

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heat buildings, make electricity and power vehicles, with the United States in the vanguard. Emissions from land-use change have also been growing, though not as rapidly as from fossil fuel combustion. And here, it is worth noting, the United States is actually playing a constructive role: for the past half century, the United States has served as a "sink" for carbon, capturing GHG in an expanded stock of trees and other vegetation.

Since 1992, virtually all governments have signed the United Nations Framework Convention on Climate Change, agreeing in principle to do their part in stabilizing GHG levels. Considerable attention has been given to ways to decrease (or at least to decelerate growth in) emissions of CO2 from fossil fuel combustion. Research has been undertaken on ways to increase the rate at which oceans extract and store carbon from the atmosphere, and efforts are under way to find cost-effective means to remove CO2 from stack gases at power plants and then store it underground – so-called carbon capture and storage.

Most relevant here, researchers are working on ways to increase the rate at which ecosystems scrub carbon dioxide from the atmosphere and store the carbon in plant material, decomposing detritus and organic topsoil. The Kyoto Protocol of 1997 blesses this approach as part of a broader strategy for individual countries to meet their obligations to attain their CO2 reduction targets.

Much of the interest in such biological carbon sequestration, of course, follows from the expectation that it could provide a lot of bang for a buck (yen, euro, etc.). And since Washington promises to create a market-oriented GHG reduction program that gives businesses considerable leeway in how they meet their goals, the question of how carbon sequestration compares with alternatives (like switching fuels) is now front and center.

PAYING THE BILL

The cost of carbon sequestration through changing land use is expressed in terms of dollars per metric ton of carbon stored. The denominator in this fraction – the carbon captured – is determined by forest management practices, tree species selection, location characteristics and disposition of the forest products created for purposes of storage. The numerator is the cost of land, planting and forest management – not to mention secondary costs or benefits, like non-climate envi-

Where Carbon Sequestration is Cheapest

Thanks largely to the fact that acreage planted in conventional crops has shrunk drastically east of the Appalachian Mountains, far more of the United States is covered in trees today than a century ago. The same cannot be said, though, for much of Africa, Latin America and Asia, where vast swaths of forest land have been cleared for firewood, to make way for growing populations and their farms, or to harvest highly prized first-growth hardwoods. Remaining forest land is threatened by development.

Take the case of Ghana. The Ghanaian rain forest has been reduced in size by 80 percent in the last half century. Now, spurred by the prospect of earning credits that can be used to offset private emissions under Europe's cap-and-trade climate change program, entrepreneurs are pushing back.

In partnership with ArborCarb, a British start-up specializing in reforestation, Ghana is planting nearly 24 million trees. The trees -- all tropical hardwoods, most of them indigenous -- offer the potential of sequestering about nine million tons of carbon dioxide over the project's life. ArborCarb's goal, of course, is to do well by doing good, selling the carbon credits for more than the cost of the project.

Not everybody likes what he sees. Critics say that carbon-offset programs shift the developed world's responsibilities onto developing countries, and in the process reduce the land available for small-scale agriculture. Forestry-offset schemes are also taking fire from skeptics who point out that the amount of carbon sequestered is difficult to verify.

The latter issue is probably not a major problem here. The project will be independently audited every year, and the measurement of carbon sequestered will be in net terms. That is, carbon emitted in forest management, as well as carbon emitted by trees that die naturally and are left to decay, is netted from the calculations.

Whatever one thinks of the merits of specific sequestration projects, a couple of things are clear: First, most of the low-hanging fruit in carbon capture lies in the rain forests of the tropics and the subtropics. Second, carbon-offset programs are one of the few promising ways to draw developing countries into the climate-change coalition. All told, it's hard to imagine a successful approach to containing global warming that doesn't include effective incentives to roll back the bulldozers.

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ronmental impacts and, of course, the use-value of the wood.

A variety of practices affect the rate of carbon sequestration. Two of them – forestation of agricultural land and reforestation of harvested or burned forest land – are usually thought of as "plantation" methods.

Four others are essentially modifications of management practices in existing forests. These are modifications of the tree species grown to emphasize carbon storage, adoption of low-impact harvesting methods to reduce carbon releases, lengthening of forest rotation cycles, and preservation of forest land that might otherwise be developed. Thus, the potential for storage in the United States varies widely – from 0.9 to 4.6 tons per acre annually.

The most important factor affecting the cost of forestry-based carbon sequestration in the United States is the cost of land, which largely turns on its value in alternative uses – conventional agriculture or urban development. But, of course, initial treatment and follow-on maintenance (fertilization, thinning, security, etc.) contribute to the overall costs, too. At the extreme, some carbon sequestration practices might pay for themselves by increasing the yield of lumber, in which case the carbon-scrubbing benefits would be a costless bonus.

At first blush, it would seem that since forest products are created in the process of carbon sequestration, an anticipated increase in the prices of forest-products relative to agricultural crops that could be grown on the land would have the unambiguous effect of reducing the net cost of carbon storage. Things are not quite this simple, however, because an increase in forest-product prices can create incentives for more frequent harvesting, which in turn can increase sequestration costs. So the net impact of higher forest product prices is an open question – one whose answer will depend heavily on the financial burden of delaying revenues – in economic parlance, the "discount rate" – for the landowners.

Indeed, because of the long time horizons relevant for analyzing the costs of carbon sequestration – trees take decades to mature – estimates are highly sensitive to discount rates. I use a 5 percent rate, the rate commonly employed to discount future costs and benefits in the analysis of public projects and policies.

AN OFFER THEY WOULDN'T REFUSE…

Policymakers have a number of ways to induce increases in forest carbon sequestration. One approach is the carrot: incentive payments, tax credits or cost-sharing. Alternatively, the government could tax undesirable land-use changes and practices, mandate specific private forest management practices, or establish a cap-and-trade carbon-rights system that creates incentives for carbon emitters to pay others (among them, forest owners) to offset their emissions. In addition, the government could expand its own forest plantations on public lands.

In aligning private interests with those of the public, it is generally most cost-effective to provide outcome-based incentives. Here, this means rewarding actual increases in carbon sequestration rather than rewarding land-use practices that might (or might not) increase sequestration. By rewarding outcomes, the government maximizes the incentive for individuals to choose methods tailored to local conditions and, equally important, to invent ways to get more storage per dollar spent.

The simplest program design would be one that effectively taxes the release of carbon from land-use changes while providing subsidies for carbon capture. A cap-and-trade program could more or less mimic the result without invoking the T word. And since Uncle Sam owns so much of the undeveloped land in the United States, there would be room here for direct government action in the form of forest planting and maintenance with an eye toward enhanced sequestration.

NUMBERS, PLEASE

In light of the host of factors that affect the cost and quantity of carbon captured, it's no surprise that researchers have reached widely varying conclusions about the prospects for this approach to slowing climate change. In a 2005 report for the Pew Center on Global Climate Change, Kenneth Richards of Indiana University and I reviewed the best available studies in order to get a better handle on the issue. We converted past estimates to common units of marginal cost by adjusting for program size (measured in tons of carbon sequestered per year), applying a consistent discount rate of 5 percent to both costs and sequestered carbon, and assuming a standardized geographic scope covering the 48 contiguous states.

This considerably narrowed the range of plausible estimates. Indeed, the dispersion is no greater than that typically associated with cost estimates for carbon abatement through fuel switching and energy efficiency improvements. The range of marginal cost estimates is particularly narrow up to 300 million tons of carbon sequestered per year, with nearly all estimates falling in the range of $10 to $30 per ton of CO2 (in 2008 dollars). The results also suggest that considerably more – perhaps as much as 500 million to one billion tons – could be stored at reasonable cost. The range of cost estimates is greater – but not much greater – for these more ambitious sequestration goals. At 600 million tons per year, estimates of marginal cost per ton of CO2 range from $12 to $37.

THE BOTTOM LINE

To get a better sense of the potential for carbon sequestration in the United States, we derived a single estimate of likely costs from the past studies – what amounts to a "central tendency" of marginal costs. Restricting attention to the range from zero to 500 million tons of sequestration annually, we found a fairly proportional relationship between unit cost and quantity, with each additional ton of CO2 sequestered costing about $25.

How does that $25 per ton figure compare with the costs of reducing greenhouse gas emissions? The Energy Department estimates that the cap-and-trade legislation passed earlier in the year by the House – the Waxman-Markey bill – would lead to emissions-allowance prices of about $32 in 2020 and $65 in 2030. From this perspective, then, 500 million tons of forest-based carbon sequestration a year at $25 a ton looks like an attractive investment.

Drilling a bit deeper, we compared sequestration with the estimates of the costs of the major emissions-containment alternatives. Opportunities for fuel switching from coal to more carbon-efficient petroleum to yet-more carbon-efficient natural gas arise at costs of about $20 to $30 per ton of CO2. Renewable energy (solar, wind, biofuels, etc.) becomes competitive at $35 to $50 per ton of CO2. New nuclear capacity could pay for itself (though not necessarily for the imponderable risks associated with fuel theft and waste storage) at about $50 per ton of carbon . Carbon capture and storage at United States power plants – the technology being promoted by the coal industry – would probably cost somewhere in the range of $75 to $150 per ton.

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As a thought experiment, consider what an efficient program that would have brought annual United States GHG emissions to 7 percent below 1990 levels over the period 2008-12 – the nation's obligation under the Kyoto Protocol, had the United States Senate ratified it – might have looked like. The target would have required a reduction of about 2.1 billion tons of CO2 in 2010. To meet that figure at minimum cost, about one-third of the reduction would have been achieved through forest-based sequestration, with the rest coming through energy conservation and fuel switching.

It's clear, then, that sequestration belongs in a cost-effective "portfolio" of approaches to reducing net U.S. emissions of carbon dioxide. But keep in mind the magnitude of the initiative needed to get from here to there. The amount of land involved would be considerable: To sequester just 50 million tons in a cost-effective manner would require approximately 27 million acres – an area more than eight times the size of Connecticut. As for the price tag, the annualized cost for a 50 million ton program would be a relatively modest $1.1 billion, but most of the cost would be incurred upfront. All told, the present value of the bill would run to about $23 billion.

Note, moreover, that 50 million tons a year is a small fraction of the total sequestration needed in a cost-effective effort to hit the Kyoto target. Needless to say, a program of the appropriate size would have to be put into effect over many years.

Carbon sequestration poses daunting challenges. How should incentives be structured? How much of the program should be implemented on public land? How would the government manage compliance over very long periods? But it is important to keep at least one eye on the prize: Forest-based carbon sequestration promises to be one of the cheapest ways to contain climate change.

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