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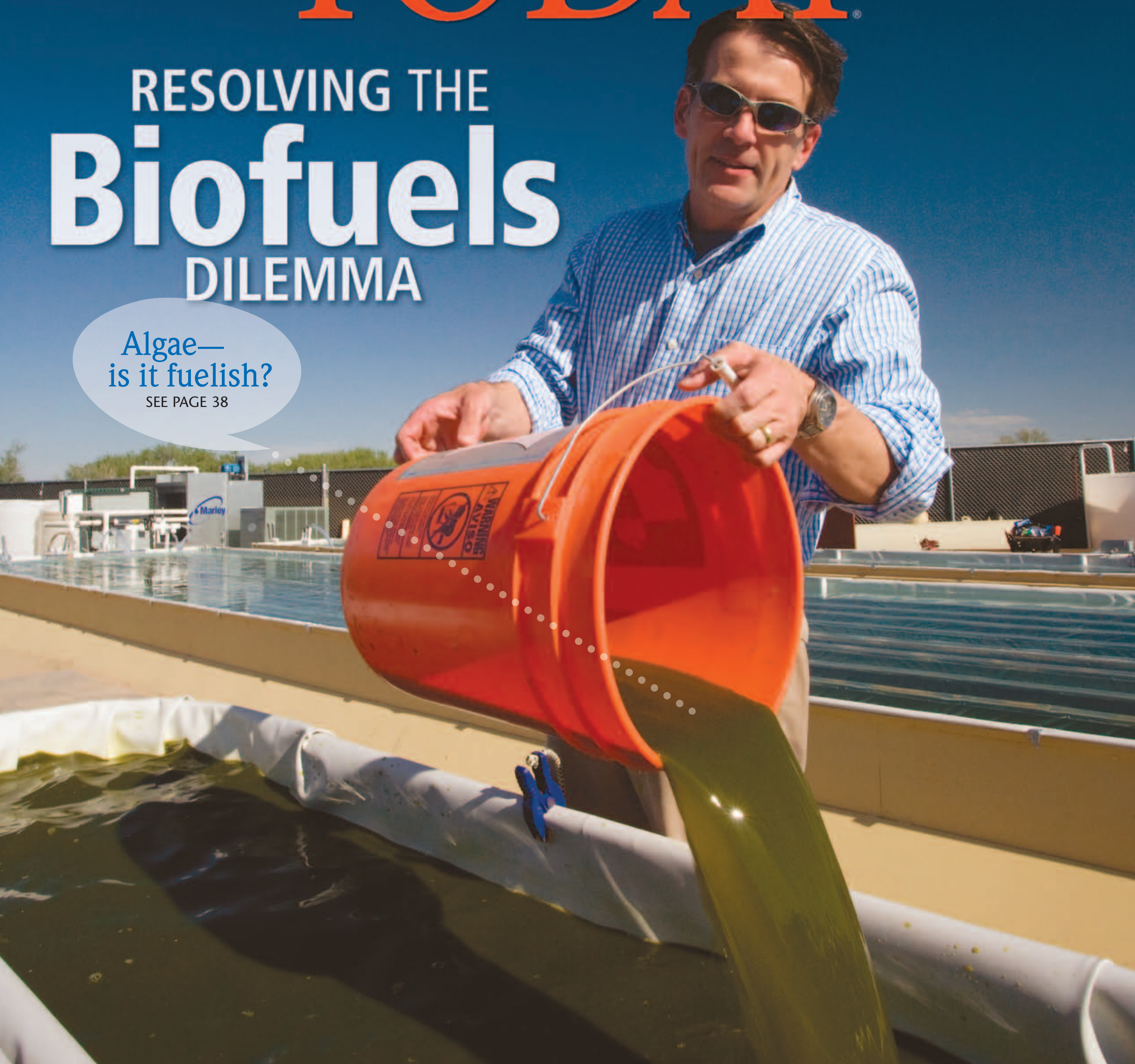

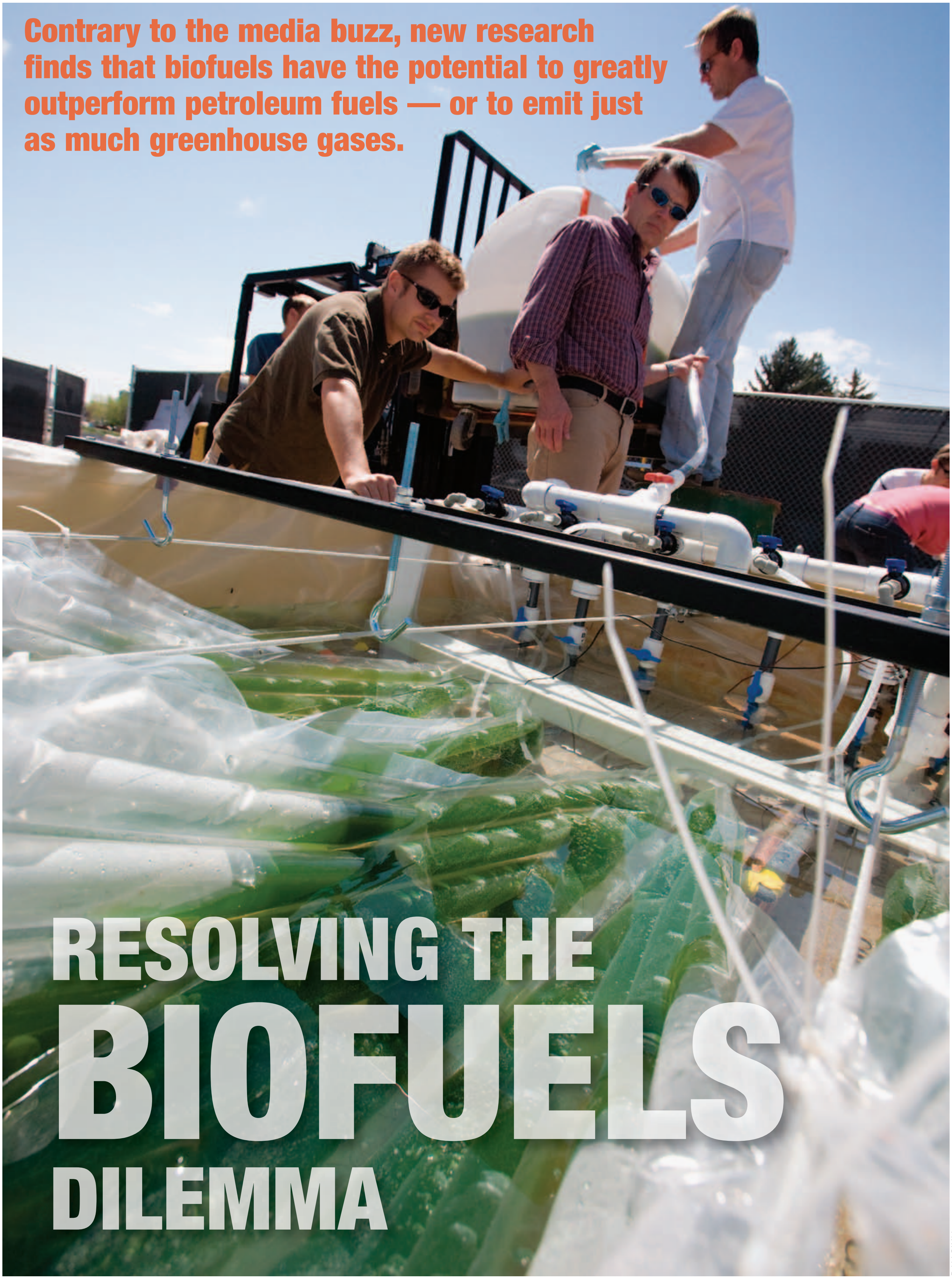

Contrary to the media buzz, new research finds that biofuels have the potential to greatly outperform petroleum fuels — or to emit just as much greenhouse gases.

RESOLVING THE BIOFUELS DILEMMA

DAN BIHN

By Carol Werner

Biofuels have been touted in recent years as a leading solution to many of our nation's challenges. In December the president signed into law the Energy Independence and Security Act of 2007, including a substantially increased renewable fuels standard. This standard calls for biofuels production to reach 36 billion gallons by 2022, with 21 billion gallons of that amount to be advanced biofuels — those derived from biomass other than corn starch and emitting at least 50 percent less greenhouse gases compared to gasoline or diesel. Congress has strongly supported expanded development of biofuels for energy security and economic benefits and to reduce greenhouse emissions. Not even concerns about biofuels' effect on global food prices have been a stopper; proponents argued that they could be addressed by advancing nonfood feedstocks like switch grass. Then, in February, *Science* published two articles that call into question the carbon-neutrality of biofuels. The articles have generated considerable doubt and controversy regarding the true benefits of biofuels.

Specifically, the studies identify situations in which certain biofuels may produce greater greenhouse gas emissions than conventional petroleum fuels if, for example, producing them has resulted in rainforest deforestation or destruction of other ecosystems that store vast amounts of carbon. To a large extent, the shift in public opinion following publication of these articles is understandable. When produced using unsustainable practices, biofuels have the inherent potential to negatively affect soils, water resources, biodiversity and additional social and environmental factors. Furthermore, as the *Science* papers illustrate, direct and indirect emissions from certain biofuels have the potential to rival or even exceed emissions from equivalent petroleum fuels during a given timeframe.

Unfortunately, the media have cited these studies frequently and erroneously as evidence that these problems are universal for all types of biofuels in all locations. On the contrary, both papers support a very different conclusion: *that direct and indirect emissions from biofuels vary considerably depending on where they are produced and what feedstocks are used.* In fact, the authors of both papers identify several feedstocks (as well as the most appropriate lands to produce them) that can be used to produce climate-beneficial biofuels.

PAT CORKERY, NREL

A key measure is the total energy yield per unit area. Doubling the amount of usable energy produced from a bushel of corn has the same effect as doubling the bushels produced per acre.

Avoiding Unintended Consequences

In Fargione et al., scientists from the Nature Conservancy and the University of Minnesota investigated the climate impacts of clearing forests and other ecosystems for the production of biofuels. (See Fargione, J., J. Hill, D. Tilman, S. Polasky and P. Hawthorne, "Land Clearing and the Biofuel Carbon Debt." Originally published in *Science Express* online Feb. 7; *Science* Feb. 29 DOI: 10.1126/science.1152747.) Although the use of biofuels reduces global emissions by substituting for conventional petroleum fuels, these savings are offset by any emissions that result from producing the biofuels. In this study, the authors began by calculating the total emissions from land clearing; this number constitutes the "carbon debt." Based on the size of the carbon debt, as well as the annual yield of fuels, the authors were able to calculate the number of years it would take for the landscape to repay the carbon debt through the effect of petroleum substitution. After the carbon debt is repaid, further production of biofuels will effectively reduce global emissions.

For instance, clearing lowland tropical forest in Southeast Asia to create oil palm plantations would result in an immediate spike of 610 megagrams (610 metric tons) of carbon dioxide per hectare. Based on the average annual yield of oil palm for this region, it would take 86 years to produce enough biodiesel to repay this carbon debt. For other biofuels, this figure varies quite a lot; *the greater the carbon*

Feedstocks most likely to help counter climate change are those having little effect on agricultural commodity markets, primarily agricultural wastes and feedstocks from nonagricultural lands, like algae. Facing page, Solix Biofuels and Colorado State University are developing technology to convert algae into biodiesel.

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storage in the land being cleared, the larger the carbon debt. The greater the annual yield of biofuels, the faster the carbon debt can be repaid. Clearing tropical peatland rainforest to grow oil palm would result in a carbon debt that would take 840 years to repay. On the other hand, ethanol produced from fast-growing sugarcane in the Brazilian cerrado becomes carbon-neutral after only 17 years, according to this study.

These payback periods become meaningful only in the larger context of agreed-upon global emissions targets. For example, should the global community aim to reduce emissions 80 percent by 2050, then ethanol produced on former cerrado could play a role in that strategy, whereas biodiesel from tropical peatlands could not. It is important to keep in mind, however, that natural ecosystems provide many benefits that are critical to sustaining our societies, including clean water, wildlife habitat, biodiversity, foods and medicines, wood products, flood protection, recreation and other cultural values and ecosystem services. In many (if not most) natural ecosystems, avoiding the loss of these values would outweigh the benefits that would be gained from clearing land and producing biofuels. Globally, about one-fifth of carbon emissions come from deforestation. Given the enormous and incalculable values provided to the earth by rainforests (the Amazon is often referred to as the "lungs of the planet"), it should be a global priority to conserve them rather than destroy them for short-term economic gains.

The second *Science* study (Searchinger et al.), by a group of researchers from Princeton University, Woods Hole Research Center and Iowa State University, takes a step beyond direct emissions to investigate the indirect emissions resulting from market-driven land-use change. Indirect emissions are caused when existing agricultural land is diverted from producing food to producing biofuel feedstocks. (See Searchinger, T., R. Heimlich, R.A. Houghton, F. Dong, A. Elobeid, J. Fabiosa, S. Tokgoz, D. Hayes and T. Yu. "Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land Use Change." Originally published in *Science Express* online Feb. 7; *Science* Feb. 29 DOI: 10.1126/science/1151861.) Because agricultural commodity markets are relatively inelastic (i.e., demand changes little in response to reduced supply), new farmland is likely to be brought into productivity somewhere else to compensate. The emissions created as a result of the land clearing at the end of this domino chain are referred to as *indirect* emissions. While the logic is sound, the effect is tough to quantify. The difficulties arise from the subtleties of determining just how elastic agricultural markets are. Even in the most inelastic markets, demand will decline to some degree in response to high prices caused by reduced supply. In the case of agricultural commodities, this effect will likely be most pronounced in the demand for meat and other "luxury" foods.

In addition to accurately estimating elasticity, calculating indirect emissions depends on all the factors that affect direct emissions — assumptions regarding where new farmland will be broken out, what ecosystems will be cleared in the process, what crops will be grown, what yields can be achieved and what timeframe is being considered. Searchinger et al. describes a comprehensive model for calculating the indirect emissions of using farmland to produce corn for ethanol in the United States. The model is based on a core of established economic, agricultural and engineering models and includes interactions among all of the aforementioned key factors. The study concludes that increased use of farmland for corn ethanol will double total emissions relative to petroleum fuels over a 30-year period.

A key value of the *Science* studies is in identifying land-use effects, an important element in determining the overall impacts of biofuels.

Both *Science* papers are important steps forward in our understanding of the climate impacts of biofuels, but they are among the very first attempts to quantify these impacts. As we continue to try to understand

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this problem, a number of new models will be advanced, models that rely on different assumptions and inputs and produce different results. Scientists will also need to quantify these effects at the regional level for a wider variety of feedstocks and fuel types. The primary value of these initial studies is in identifying and bringing attention to land-use effects, an important element in determining the overall impacts of biofuels. Our bottom line is that we do want to improve sustainability without creating unintended consequences.

Shifting to High-Yield, Nonfood Feedstocks

Given the state of the science, along with recent findings that suggest we must reduce global carbon dioxide levels to 350 parts per million to avoid catastrophic damage to the earth, we should focus on those fuels and feedstocks that offer the most promise for helping to combat climate change. To that end, it is important to first identify those fuels and feedstocks with the greatest potential to come up short. In general, these are fuels produced from feedstocks grown on either (a) newly cleared land, or (b) existing agricultural land that would otherwise be used to produce food. In the first instance, the most prudent action would be to simply avoid clearing forests, grasslands and other carbon-rich ecosystems. In the second instance, we should make a concerted effort to focus on those feedstocks that will not affect agricultural commodity markets. These feedstocks fall into two categories: **agricultural wastes/residues** and **feedstocks from non-agricultural lands**.

An enormous quantity and variety of wastes and residues are produced in the process of growing and harvesting food and fiber crops. Straw, stover, prunings, unsellable produce and other unused biomass forms a significant portion of the plant matter produced in a crop. Assuming that enough is left on the soil to maintain nutrient levels and protect against erosion, much of this material could be used in the production of biofuels without setting aside any additional land or affecting the global supply of agricultural commodities. In fact, using this material in many cases would relieve farmers from having to dispose of it, turning an expense into a revenue stream. Livestock manure is an especially abundant form of biomass and one associated with a host of water and air-quality problems. We have considerable incentive, both economically and environmentally, to turn this troublesome pollutant into a valuable product. In addition to wastes and residues generated directly on the farm, a significant quantity of agriculture-derived wastes is produced as a result of secondary processing — food scraps, yellow grease and restaurant waste being some of the more prominent examples. Large amounts of money and infrastructure are dedicated to the treatment and disposal of many of these materials.

Nonagricultural lands are also potential sources of renewable, climate-friendly feedstocks disconnected from agricultural commodity markets. Small-diameter, low-quality trees ("culls"), brush and slash are regularly harvested from forests as part of stand-improvement treatments, habitat management and forest-restoration activities. Using these materials as feedstocks could increase the cost-effectiveness of timber production, wildlife management, forest restoration and other objectives of sustainable forestry. Large acreages of degraded lands exist where former forests, meadows, grasslands and farmlands were used unsustainably and then abandoned. Planting these lands with fast-growing trees, shrubs and grasses could be a cost-effective way to secure soils, reduce erosion and provide renewable feedstocks. Even cities, suburbs and other settled areas can provide a large variety and amount of feedstocks, including municipal wastes, landscape clippings and urban wood waste.

In addition to emphasizing the importance of focusing on wastes, residues and other noncommodity feedstocks, the *Science* papers demonstrate that yield rates are critical in determining the climate impacts of biofuels. In Fargione et al., we can see that doubling the annual yield will cut the carbon payback period in half. Searchinger et al. calculated indirect emissions that were 50 percent that of corn ethanol for ethanol made from fast-growing switchgrass. Selecting and breeding fast-growing plant species and cultivars is an important

WINSTON DAVIDIAN/ISTOCKPHOTO.COM

As Food Prices Spike, Blame Rising Oil Costs

In recent months, headlines and commentators alike have heaped blame for rising food prices on ethanol production. In fact, while increased production undoubtedly has played a role, that part is small compared to the confluence of factors involved. It's amazing what $120 per barrel oil does to food prices.

As an April study by Texas A&M University explained, "the underlying force driving changes in the agriculture industry, along with the economy as a whole, is overall higher energy costs." According to the U.S. Department of Agriculture, about 20 percent of the consumer food dollar can be attributed to its underlying food (farm) value. Because processed foods are so prevalent in the United States, higher commodity prices have only a small impact on retail food prices. Other major factors include a protracted drought in Australia (a major global wheat producer); significant rising demand for meat (and animal feeds) in China and India; the many countries (especially in southeast Asia) that began last fall to put export restrictions or bans on their wheat and rice production; weakness of the U.S. dollar; and a concerted publicity effort by the Groceries Manufacturers of America to attack corn ethanol production and urge a rollback of the recently enacted renewable fuels standard.

Ethanol actually may be helping your pocketbook. According to analysis by Merrill Lynch, gasoline prices would be 15 percent higher without biofuels.

SHELLY HARRISON

It is prudent action to focus on feedstocks such as agricultural wastes and residues. Here, a Verenium employee handles sugar cane bagasse biomass (residue left after product extraction) to be used at the company's cellulosic ethanol demonstration-scale plant in Jennings, La. Commissioned in May, the facility is the first of its kind in the nation.

step to producing climate-positive biofuels. Feedstock yields, however, are only one component of a more fundamental measure, the total energy yield per unit area. *Doubling the amount of usable energy produced from one bushel of corn will have the same effect as doubling the amount of bushels produced per acre.* In fact, it may have an even larger effect when emissions from feedstock production, processing and transportation are taken into account.

An important aspect of the climate impacts of biofuels not addressed in the *Science* papers is the carbon-storing ability of feedstock-producing lands. Scientists have assumed that growing and harvesting biomass feedstocks either reduces or at best has no effect on carbon storage in the landscape. In many natural systems, however, increased use of biomass has the potential to result in more carbon storage. For instance, removing biomass from overstocked stands in many forest types can reduce greenhouse gas emissions associated with catastrophic fires. Reclaiming degraded or desertified lands with grasses or trees can greatly increase carbon storage in soils. The positive climate impacts of these activities must be taken into account when attempting to quantify the total impacts of a certain biofuel.

Pursuing a Climate-Positive Portfolio

Clearly the climate impacts of a particular biofuel are contingent on a number of factors. Depending on management practices and site characteristics, biofuels have the inherent potential to greatly outperform petroleum fuels or to rival them as greenhouse gas emitters. *We can maximize the positive climate impacts of biofuels by focusing on wastes and residues, treading lightly on agricultural commodity markets, increasing yields and productivity, and aiming to use feedstocks that increase the carbon storage of the lands on which they are grown.*

Given this discussion, it is deeply troubling that the newly enacted renewable fuels standard precludes the use of biomass materials from any federal forest lands — despite congressional, state and local priorities to reduce hazardous fuels to help prevent catastrophic wildfires. The use of such material can help address multiple goals for more sustainable forest management — and can provide feedstocks drawn from waste/residues that do not affect land-use change or draw from agricultural commodity production. This disconnect in the renewable fuels standard needs to be corrected.

> We should use the onslaught of concern to help ensure we get it right as we seek to implement sustainable pathways. But we should be careful not to throw the baby out with the bathwater.

It also is important to note that renewable biomass can be used effectively in a number of energy applications beyond liquid transportation fuels. Woody biomass can be combusted at high efficiency (up to 90 percent) to produce renewable thermal energy, electric power or combined heat and power applications. Cofiring experiments with both wood and switchgrass have demonstrated potential to reduce fossil fuel use and improve emissions in traditional coal-fired power plants. Anaerobic digestion, a process in which microorganisms break down biodegradable material in the absence of oxygen, has been used to produce both electric power and thermal energy from livestock manure and other biomass.

The United States is blessed with an abundance of biomass to serve these applications — but it is critical to know what kinds of biomass are available where, in what quantities on a sustainable basis and at what price. That is why a more comprehensive national biomass assessment is needed and why we should conduct biomass assessments at the state/regional level to ascertain the true variety of feedstocks available. These assessments need to consider the amount and kinds of wastes, including everything from food processing to prunings to manure to wastewater treatment facilities. Wastes must become resources.

We should use the onslaught of concern about biofuels to help ensure we get it right as we seek to implement sustainable pathways. But we should be careful not to throw the baby out with the bathwater, as some vested interests would like. Biofuels, and biomass more generally, are an important piece of the solution. That said, perhaps the most important thing we can do is to recognize that our societies will be better off the more energy efficient we are and develop a portfolio of solutions to reduce demand. Improving the efficiency of our vehicles, using biofuels with plug-in vehicles and greening the grid with distributed renewable energy can make the whole picture more manageable and more sustainable. Reducing travel demand through better community design and better mass transit options will also help. Let's not forget that the land-use change represented by converting countless acres of agricultural land to sprawl every year also represents huge carbon releases. Who is accounting for that?

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