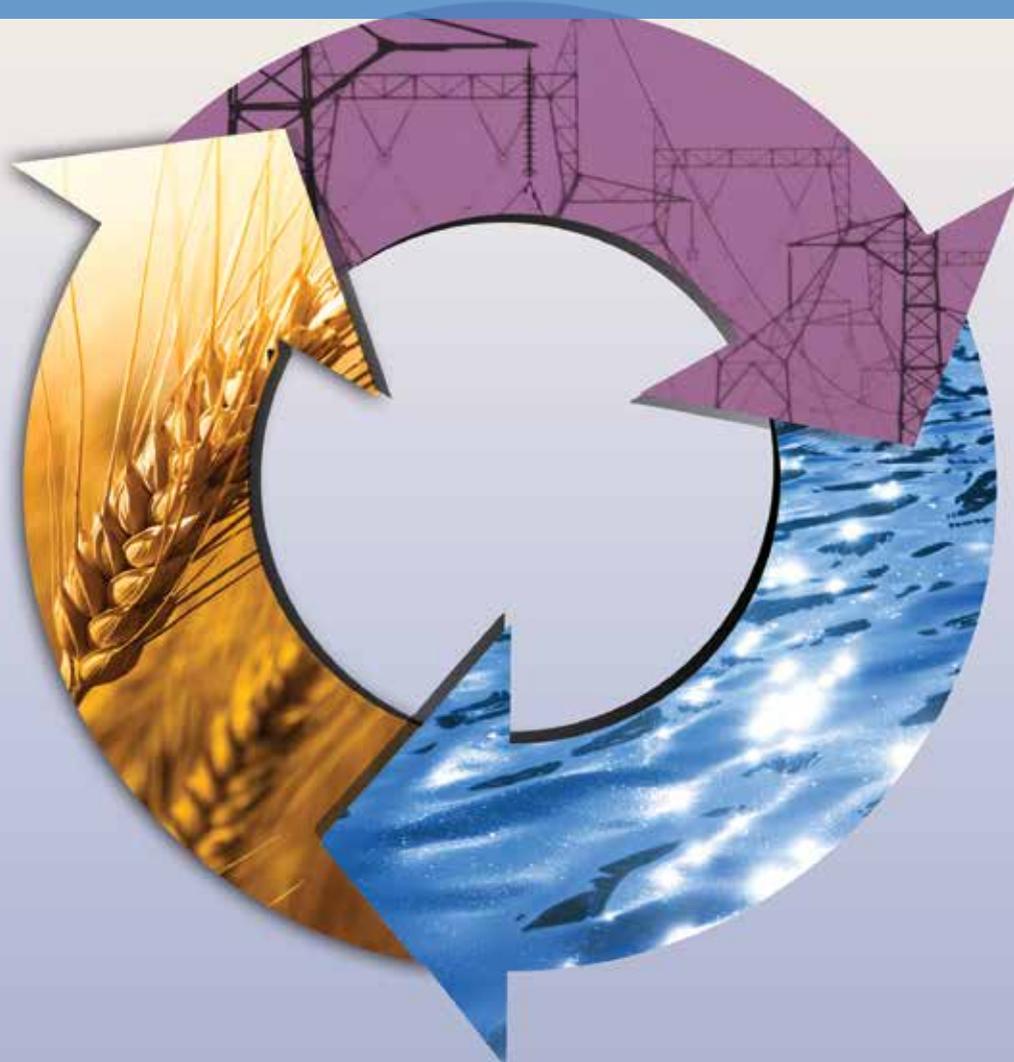


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Special Report

THE NEXUS OF FOOD, ENERGY AND WATER



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The Initiative for Global Environmental Leadership (IGEL) and Knowledge@Wharton have partnered to create this special report on business and the environment. We are most grateful to Nestle Waters and Xerox for supporting the collaboration and funding of this edition.



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The Nexus of Food, Energy and Water

Already more than one billion people lack access to clean drinking water, sufficient food and electricity, and the global population is growing by some 80 million people every year. By 2030, the nine billion people living on earth will need 30% more water, 40% more energy and 50% more food to survive.

Given the complex relationships among all three resources — the nexus of food, energy and water — meeting these demands will require thinking in terms of systems, not silos. It will take collaborative approaches that embrace rather than battle natural processes. And it will mean new technologies and approaches to everything from bio-fuels to desalination. This special report, produced in coordination with Wharton's Initiative for Global Environmental Leadership (IGEL), takes a close look at the key issues.

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It's increasingly hard to argue for business as usual when the stakes are so high, and yet the corporate response to issues around resource scarcity and the environment is not nearly equal to the size of the problem. Still, companies are beginning to move beyond public relations benefits to give sustainability a seat at the table. They are realizing that the inter-related problems of food, energy and water threaten their own sustainability, and that there is a business opportunity in increasing efficiency and reducing waste.

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Once we exhaust the world's supply of fresh water, there isn't any more. Or is there? The amount of fresh water available globally has not changed for eons, so conservation has gained some traction as some of the wealthiest and driest nations moved to desalination, while most cannot afford the huge energy costs that come with it. But breakthroughs have dramatically cut desalination's energy consumption, and now the industry is taking the next step by looking to switch from fossil fuels to renewables. Private enterprise is helping to hasten the day when the oceans may become virtually unlimited sources of fresh water.

Growing Food, Growing Problems 11

Agriculture now produces enough food to feed everyone on earth. So why are a billion people still going hungry? For years the Green Revolution seemed to promise an end to hunger, but as world population heads towards nine billion, and more farmers move to urban centers, global hunger has reached crisis proportions. Production of more and increasingly expensive food is not the answer, so attention is shifting to working with local farmers where needs are greatest. In place of a single answer to global hunger, a promising paradigm is taking shape — holistic agriculture grounded in science and government policies, all underpinned by new technologies.

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Ethanol production uses about 40% of the U.S. corn crop, and has been blamed for sharply rising food prices — even as the federal government ramps up both quotas and use of the fuel in gasoline. But cellulosic ethanol, produced from the inedible parts of plants and not yet commercially available in the U.S., offers a sustainable alternative. Brazil's efficient sugarcane fuel production provides a model.



Resource Scarcity Will Recast Corporate Environmental Behavior

Today, some 1.1 billion people lack clean drinking water, 1.3 billion are without electricity and more than one billion are hungry. Addressing these growing and connected nexus crises is, or should be, a major priority for business. It isn't yet, but there are signs that companies are starting to realize the stakes and make commitments to being part of the solution — often with low-waste programs that also save them money.

It's increasingly hard to argue for business as usual when the stakes are so high. Alan M. Kelly, emeritus dean of the University of Pennsylvania School of Veterinary Medicine, said in a recent talk that because of population increases, urbanization, poor cultivation practices, drought and other factors, the world is losing 30 million acres of arable land per year. By 2030, available arable land per person will shrink by from a half to a third of an acre.

"An era of low food prices is coming to an end, in part because of low water availability," he said. "The cities are the locus of almost all economic expansion, and by 2050 there will be three billion middle-class people in the developing world, moving up the food chain."

At the "Nexus of Energy, Food and Water" workshop sponsored by the Initiative for Global Environmental Leadership (IGEL) at Wharton, many speakers pointed out that there will soon be nine billion people on earth with rising expectations. Just as governments have to adjust to changing environmental priorities, so do corporations that do business on a global scale.

Business leaders will need to incorporate knowledge about the nexus of food, water and energy — and how these forces will shape the world — into routine business planning, many of

the speakers agreed. Although sustainability has become a watchword for companies, which often chart their progress in annual reports, the response is not yet equal to the size of the problem. With rising awareness that holistic thinking is a smart business strategy, that is slowly changing.

Bernard David, an entrepreneur and senior fellow at IGEL, noted that given limited resources, the search for profits has to take a longer-term view. "Sustainability is a systems problem, and we're not wired to think in terms of systems," David said.

Humanity's Final Exam

Andrew Winston, founder of Winston Eco-Strategies, and co-author of the influential book *Green to Gold*, said at the conference that nexus challenges are "the final exam for humanity, and it's the biggest test we've ever faced. It's time to set radical efficiency goals.... Seeing a good payback quickly on the 'easy' stuff — eco-efficiency that saves energy and water — always convinces people that there's benefit in this."

And although there has been some progress, sustainable environmental policies "are not getting to scale," notes the World Resources Institute (WRI) in a 2013 working paper entitled, "Aligning Profit and Environmental Sustainability: Stories from Industry." A good example is climate change.

In 2012, extreme weather events, linked to a warmer world, were estimated to cost the U.S. \$60 billion. Meanwhile, the effects of global warming could be amplified by 1,200 new coal-burning power plants proposed worldwide. Yet, while more than 300 of the S&P 500 companies report their greenhouse gas emissions to the Carbon Disclosure Project, WRI notes that corporate responses to climate change and natural resource scarcity often

are “marginalized” and are not a high priority compared with “core” concerns such as “product manufacturing or marketing campaigns to attract new clients.”

However, dwindling supplies of the resources on which companies depend and new consumer preferences are forcing executives to pay attention. WRI believes the priorities are clear:

- Change the corporate charter to liberate sustainability from its “silo” and integrate it into long-term planning — on a par with other operations that create value.
- Give sustainability a seat at the table where capital is allocated. When companies use traditional financial measures that generally fail to give fair value to natural resources, environmental protection often loses out. Better metrics are needed to account for the planetary impact of business decisions.
- Work to integrate the goals of financial managers with those on the environmental team, so they can present to management as a unified voice.

Nexus-conscious companies are focused on making real gains in energy efficiency, water conservation and food use. They’ve absorbed the necessary lessons, and their ranks are likely to grow.

Energy Efficiency: Challenges and Opportunities

Neil Hawkins, vice president of sustainability and environment, health and safety at the Dow Chemical Company, referenced the big increases in population and middle class consumers on the way. “They want to eat more meat, and that’s how we get food competing with biofuel feedstocks — it’s a big change.” The competition from ethanol complicates the picture, Hawkins said. “In a business-as-usual scenario, we’d have to double agricultural output by 2050. It’s pretty challenging.” Quoting Pavan Sukhdev, a green consultant in India, he added: “We use nature because it’s valuable, but we lose it because it’s free.”

Charlene Wall-Warren, North American sustainability manager for BASF, told the IGEL audience that her company hopes to increase its energy efficiency 35% by 2020, while also reducing its withdrawal of drinking water from supply sources for production by half (compared to 2010).

Johnson & Johnson has made a similar commitment. Jed Richardson, the company’s global

energy director, said the company will increase its clean energy use to 50 megawatts by 2015, reduce fleet CO2 emissions 20% per mile and facility CO2 emissions also 20% by 2020, while cutting water consumption 10% at manufacturing and R&D facilities.

Corporations make a major contribution to relieving nexus pressures by producing their own zero-emission solar, wind and geothermal power. Richardson said the company is close to meeting its 2015 goal already, having installed 45 megawatts of renewable energy at its facilities, including 34 solar projects. One of these is a 4.1-megawatt spread over 18 acres in Titusville, New Jersey. It provides approximately 70% of the site’s energy use.

Food Matters

The potential gains from agricultural reform are huge. IGEL’s David pointed out that food production takes 50% of available land in the U.S., 80% of the fresh water and 10% of the national energy budget.

But, echoing Winston, David said that 40% of that American food goes uneaten. “Some 20 pounds of food per person are wasted each month. Twenty five percent of all fresh water is wasted, and 25% of methane emissions are from uneaten rotted food in landfills. But if just 15% of the wasted food was saved, it could feed 25 million Americans. It takes seven to 10 calories of energy to produce one calorie of edible food.”

Because of inadequate storage and poor storage, some 30% to 40% of the world’s food crops are lost between the field and the marketplace, according to Tim Fox, head of energy and environment at Britain’s Institution of Mechanical Engineers. And that means water waste, too. A quarter of the fresh water taken by humans is used to produce food that is wasted or lost.

Because it takes eight kilos of grain to produce one pound of meat, Sir Gordon Conway, professor of international development at Imperial College, suggests that a switch to a vegetarian diet could be an effective global solution. “But I don’t see that happening,” he said. In any case, Tamara McCann, former chief counsel for environment and sustainability at the National Cattlemen’s Beef Association, noted that meat is becoming more efficient, with total U.S. beef production up dramatically even as the size of the cattle herd has been declining since 1977.

McCann said that the beef industry — frequently criticized for inefficiency — has drastically reduced its water use per pound of beef. The growing practice of biogas recovery from animal facilities — using dairy farm methane to produce electricity in gas turbines, for example — also increases efficiency. And she pointed to a 2007 Washington State University study that found that ranchers are producing 13% more beef from 30% fewer cattle than in 1977, using 33% less land, requiring 12% less water and reducing carbon emissions by 16%.

Of course, the meat industry's confinement systems are still a major polluter of waterways, and advocates for grass-fed beef make a compelling case for natural grazing in place of huge grain feedlots. Judith Schwartz' book *Cows Save the Planet* even argues that properly managed grazing can help restore soil health. McCann argues, however, that grazing all American beef cattle would require an additional 131 million acres, equivalent to "75% of the land area of Texas."

A Huge Business Opportunity

Former U.S. Attorney General John Ashcroft, also a Wharton conference speaker, emphasized the growing importance of nexus issues. "If the water runs out, it will be more important than if the oil runs out. Corporate leaders can redefine the possible in these areas. When companies take initiative with intensity and enthusiasm, they can actually lead the customer."

As for companies taking the lead, Coca-Cola and Nestlé Waters are focusing on protecting the world's increasingly challenged freshwater supplies. For Coke, it is simply good business. The company notes in the 2011/2012 Sustainability Report that since it sells its products where it makes them, added to "the ecological and ethical imperatives that drive our water stewardship, we also have a vested business interest in preserving and improving local water sources."

Jeff Seabright, vice president of environmental and water resources at Coca-Cola, noted at the conference that water and agricultural production are tightly intertwined. "Twenty eight percent of global cultivated land is in stress and 40% of irrigated land — by 2025 it will be 73% of irrigated crops. We're approaching a pretty significant tipping point on these interrelated areas. And solving this set of challenges is the greatest business opportunity of this generation."

Succeeding at transforming company-wide operations will take more than a board vote. Seabright pointed out that Coca-Cola follows a franchise model, so it must work with 200 other companies, 500 brands, 300 independent bottling partners, and 1,000 manufacturing facilities.

Among its goals, Coca-Cola aims to increase water efficiency 25% by 2020, and that same year "safely return to communities and nature an amount of water equal to what we use in our finished beverages and their production." It wants to be a "net zero" user of water. By the end of 2011, it had balanced about 35% of the water used in its beverages.

Coca-Cola has also committed \$30 million over six years to the Replenish Africa Initiative (RAIN), which will give two million people access to safe drinking water by 2015. RAIN intends to start more than 100 water access programs in Africa.

The water crisis could cut worldwide cereal production 30% by 2030, noted Nestlé S.A. CEO Paul Bulcke, in a London speech early in 2013. Noting the issue needs urgent attention, he called for collective action by "policy makers, civil society, agriculture and other stakeholders, at local and international levels" to address water shortage.

Some 40% of Nestlé Global's factories are in regions experiencing water stress, and 10% are in areas of severe scarcity. The company is reducing its water withdrawal (in part through rainwater harvesting) at the same time it increases operating efficiency. In 2012, it began screening its factories' water use with tools developed by WWF and the German Development Finance Institution. That analysis produces a physical risk score that measures the effect of the company's withdrawals on water quantity and quality. Nestlé's water risk database is updated annually.

In the long run, the efficiencies "reduce operating costs and conserve scarce resources," says Michael Washburn, vice president of sustainability at Nestlé Waters in North America. "Yes, our projects have to pay back in a certain amount of time, but our company gives us flexibility on taking a longer time to pay back." Bottled water, meanwhile, has its own imperatives. "We produce a product that in certain quarters is controversial, and has a precise set of societal expectations," said Washburn. "We're expected to be good stewards, to be involved in responsible disposal of our packaging, and to use

energy as efficiently as possible. If we fall short on any of those things, we're confronted with a societal backlash."

Sustainability, said Washburn, in some cases provokes engagement outside the company's own boundaries. In north Florida, Nestlé works with the Suwannee River Partnership to help farmers with best practices in irrigation, and use of fertilizers and herbicides, to reduce effluent release into rivers and streams. Also in Florida, the company is working with Southern Forestry Consultants to manage its 468-acre certified tree farm for optimal soil conservation and biodiversity.

Since Nestlé Waters draws its product from springs, not rivers, why do that work with ranchers? It's about local relationships, said Washburn. We are present in 26 communities around the country where we have factories, and our employees live there and interact with stakeholders there. We actively seek positive community engagement, because it builds brand equity and local trust. It's not a selfless act, because there are benefits that come back to our company."

Rethinking What's Waste

Several other corporate spokespeople offered their views during and after the conference.

"We're at an exciting place in business history, and it's time to be radically innovative," said Gil Friend, president and CEO of Natural Logic, which helps companies develop sustainability strategies.

It's partly a supply chain issue, said Cope Willis, manager of sustainable business solutions for PricewaterhouseCoopers. "We need play-to-win strategies, and one way to do that is to take control of your supply chain and collaborate with key suppliers and stakeholders to address pervasive environmental and social issues." At Interface, which developed cutting-edge solutions for recycling carpet, having a reputation for innovation has paid off. Noted Tim Riordan, vice president for supply chain, other companies are now approaching Interface looking to use their proprietary technologies.

Dave Stangis, vice president for public affairs and corporate responsibility at Campbell Soup, said that in addition to reducing its energy use, his company is working to recycle 95% of the waste it generates globally, eliminate 100 million pounds of packaging and cut energy use by 35%, all in an effort to slash its carbon footprint by 50% in 10 years.

New Profit Streams

Radical innovation includes coming up with dramatic new uses for what was long considered "waste." Many automakers also have zero waste goals, and have gotten surprisingly far in achieving them. Ford, for instance, has 14 plants globally that are "nil to landfill," and in 2012 recycled 586,000 tons of scrap metal in North America, producing \$225 million in new revenue. General Motors reports that 105 of 156 plants globally are zero waste (meaning less than 1% of residue), and are yielding \$1 billion annually from what used to be landfill waste. Honda is also a leader, with 10 of 14 North American plants converted to zero waste.

According to Bernard David, groups such as the Natural Resources Defense Council are helping other companies find secondary markets for materials once destined for the landfill. "They're using online solutions to facilitate the sale — or donation — of rejected shipments of, say, 80,000 pounds of carrots or 40,000 pounds of overripe [but consumable] bananas," he said. It works on a smaller scale, too. David pointed to restaurants that are limiting menus, offering flexible portions (so people don't leave food on their plates) and initiating staff waste reduction initiatives. "We need to understand that food waste occurs all along the supply chain," David noted. "We need to be taking the highest and best uses for food."

Such reuse is the key to the business of Rubicon Global, which is revolutionizing the waste and recycling business. The company doesn't own landfills or truck fleets. According to Perry Moss, Rubicon Global's president, "We create revenue by reducing the cost of waste and recycling services, optimizing logistical routes and diverting material from landfills.... It's not rocket science; it's about prevention, or not generating the waste in the first place." Rubicon's approach demands local solutions — environmental savings are quickly dissipated if recovered materials must be transported long distances.

Moss said that on average, Rubicon Global saves companies 20% to 30% on their waste and recycling-related bills, and significant amounts of administrative time. It's not just food waste — some 400 million electronic devices are dumped annually in the U.S., and less than 15% are recycled. And much of the material shipped overseas for recycling is not handled in an environmentally friendly manner. Rubicon Global finds secure recycling

solutions that can be reliably listed in sustainability reports, as well as on-site data protection, and the remarketing of parts to capture value that would otherwise be lost. Working with retailers across North America, Rubicon Global has implemented transportation solutions that eliminate two to three pickups per week, per location.

As WRI pointed out, individual accomplishments — including those of the leading-edge companies — can be impressive. But they are nowhere near adding up to a solution to our global nexus challenges. Still, there is growing evidence that sustainability has a seat at the table where corporate decisions are made. And in addition to the environmental benefits, the business case is compelling.





'New Water' Offers an Ocean of Hope

Once we exhaust the world's supply of fresh water, there isn't any more. Or is there? For millennia all the fresh water we've needed has fallen from the skies and the hydrological cycle still functions as it always has: Evaporation purifies the water it extracts from the sea and condensation distributes the life-sustaining result around the planet. Having helped nourish terrestrial life, the water finds its way back to the sea and the cycle repeats.

The process purifies only a tiny fraction of the world's water, less than 3%. But since 75% of the planet's surface is covered by seawater, that has been more than enough — until recently.

Now agriculture, industry, energy production and sanitation consume vast quantities of the planet's limited fresh water; pollution renders much of what's left unfit for human consumption; and much of the rest is simply wasted. Already, nearly a billion people don't have access to safe drinking water. With the global population heading towards nine billion, and climate change disrupting weather patterns and melting glaciers of pure water back into the sea, the situation is only likely to get worse.

Given that the amount of water on the earth has not changed for eons, a great deal of attention has been focused on conserving water — reducing what we need and what we waste to a bare minimum. Much has been accomplished and much more remains to be done. But it is far from clear that these efforts alone will suffice, and it seems increasingly likely that our demand for fresh water will soon surpass the capacity of the hydrological cycle.

Desalination Offers Hope

If that happens, the only feasible solution in the near future is desalination, the use of technology to purify seawater. "Desalination is the only hope

to produce new water for future generations at affordable prices," according to Leon Awerbuch, past president and currently a director of the International Desalination Association (IDA), as well as president of Leading Edge Technologies.

The Middle East has been using desalination for 40 years, but the industry did not expand much until relatively recently. Widespread interest in desalination, especially within the business community, started in the 1990s as scientists began improving the technology, and the demand for fresh water grew more intense. Speaking at the Initiative on Global Environmental Leadership (IGEL) Conference, "The Nexus of Energy, Food and Water," Neil Hawkins, vice president of sustainability and environmental health and safety at Dow Chemical Company, noted that solving the issues of the nexus is "the greatest business opportunity in our generation." The rapid growth of the desalination industry in recent years proves his point.

Thanks to the commercialization of those scientific

"If we could produce fresh water from salt water at a low cost, that would indeed be a great service to humanity, and would dwarf any other scientific accomplishment."

—President John F. Kennedy, 1962

breakthroughs, today more than 16,000 desalination plants are producing water in 150 countries, including in China, India, Australia, Chile and the U.S. Desalination is now considered a growth

industry: “Desalination Seen Booming at 15% a Year as World Water Dries Up,” declared a recent Bloomberg headline.

Overcoming Energy Limitations

For much of its history, the desalination industry has been limited by its massive need for energy. The two desalination technologies that currently dominate the field are both energy-intensive. Reverse osmosis (RO) uses electricity to generate the high pressure needed to force seawater through semi-permeable membranes, while thermal distillation uses energy both to heat seawater and to drive the system’s pumps. This demand for energy has kept the cost of desalination too high for any but the richest, most water-starved regions of the world (Saudi Arabia has been — and is expected to remain — the largest producer and consumer of desalinated water in the world).

But growing business investment in R&D produced innovations that have greatly reduced the industry’s energy requirements. Awerbuch points to significant advances in both RO and thermal desalination. For RO technology, one of the most significant developments has been isobaric energy recovery devices (ERD). The technology exploits the fact that very little of the pressure used to force seawater through the RO membranes is consumed in the process. ERD is able to recover 98% of this energy and use it to power the intake process, virtually cutting in half the amount of energy needed to run RO plants. To put this in context, a plant equipped with ERD technology can now produce six gallons of clean water with the same amount of energy a 100-watt light bulb uses in just one hour.

Advances have also significantly reduced energy use in thermal distillation. Both multi-effect distillation (MED) and the newer, and more widely used, multi-stage flash distillation (MSF) process represent sophisticated versions of the most ancient approach to desalination: the evaporation and condensation of seawater (analogous to the natural hydrological cycle). These systems heat seawater and then run it through a series of process stages, which successively lower the atmospheric pressure. As the pressure drops, so does the boiling point of the seawater. Thus, at each stage additional water boils into steam, leaving salt behind. Thermal distillation plants are generally coupled with power plants. This dual-purpose approach further improves efficiency by using waste heat from the power plant to warm the seawater.

Continual Innovation

Efficiency in thermal distillation is measured in terms of gain output ratio (GOR), which in simple terms is the amount of clean water generated per volume of steam. The GOR has historically been about eight to one (one unit of steam has generated eight units of clean water). But Awerbuch says that some plants have already achieved a ratio of 15 to one and he foresees a 16 to one ratio in the near future

Combining reverse osmosis and thermal distillation in one hybrid plant increases energy efficiency still further. Thermal distillation produces distilled water, which exceeds drinking water standards. Since the RO water will be mixed with this ultra-pure distilled water, it can be of somewhat lower quality and still contribute to an end product that meets drinking water standards. As a result, the RO system can be run at lower pressure, saving energy and extending the life of the membrane. What’s more, heat from the thermal system is used to increase the temperature of the seawater in the RO part of the plant, further improving the efficiency of the membrane.

Membranes themselves have also been revolutionized. Over the past 25 years, improvements have increased the amount of salt extracted, extended the life of the membranes themselves and reduced costs. At the end of 2012, Dow Chemical announced a new membrane chemistry that reduces salt by 99.7% compared to traditional brackish water membranes, while also reducing energy consumption by 30%.

According to Tracy Young, global application development leader for Dow Water and Process Solutions, as the company expands its desalination business, it will be taking this new membrane chemistry beyond brackish water into other segments of the market, including seawater desalination and wastewater treatment. (There is no exact definition of brackish water, but the term generally means water that it is less salty than seawater to some degree, and therefore is less costly to de-salt).

Together, these and other breakthroughs have dramatically reduced the cost of desalination, bringing it within reach of many more countries. And innovation is continuing on several fronts, including the development of forward osmosis, a process that uses naturally occurring, unassisted osmotic pressure rather than reverse osmotic pressure, which has to be powered artificially.

A New Approach — Off-peak Pricing

In the Middle East, power consumption soars in the summer months. In parts of Saudi Arabia, for instance, peaks can go above 120 degrees Fahrenheit and air conditioning units run continually. But in winter, power use drops by 30%. One new idea, reports Awerbuch: Use idle, winter power capacity to produce more desalinated water than needed. The excess water would be stored in underground aquifers to be tapped in the summer, when power is much more expensive. Such desalination aquifer storage and recovery (DASR) produces more water at lower cost, and also increases the efficiency of the otherwise underutilized power plants.

The practice of storing water in aquifers for later use is widespread in the U.S. Just as the nation developed strategic underground reserves of petroleum years ago, many areas with dwindling water supplies are now resorting to a similar strategy for water. The Environmental Protection Agency (EPA) estimates that more than 1,000 aquifer storage and recovery (ASR) wells are currently operating or waiting to be used, mostly in dry regions of the country. Few areas outside the U.S. are storing significant amounts of water, but given the strategic importance of securing adequate supplies, more may turn to DASR in the future.

The Renewable Energy Card

Most of the world's desalination plants still tap fossil fuels, which makes them unsustainable long term environmentally and economically, no matter how efficient their energy use.

In the Middle East and North Africa (MENA) region, the obvious choice is to convert the plants from oil to solar power, which potentially is unlimited. The region could generate enough solar energy to meet current world demand several times over, According to a 2012 report by the World Bank. Replacing fossil fuels would also significantly reduce carbon dioxide emissions, a chief contributor to climate change.

Of the various solar technologies available, says the World Bank report, "Concentrating solar power (CSP) is the best match because it is scalable to demand; can provide both peak and base load electricity; and with heat storage and oversized solar collectors, it can provide a firm power supply 24 hours a day."

The conversion from fossil fuel to solar energy in the MENA region will take time. Current plants will not be decommissioned until 2041-2043, and it will take further research and development to make solar power costs manageable. In the meantime, Saudi Arabia has already developed a number of solar-powered desalination plants, and recently started up the first large-scale solar-powered seawater reverse osmosis (SWRO) plant in the world in Al-Khafji, near the Kuwait border.

Eight thousand miles away in Australia, the world's driest inhabited continent, wind is far more plentiful than sunshine. But a lack of fresh water remains a significant problem. So with severe droughts already dominating recent history, and climate change threatening more to come, Australia now views desalination as a strategic necessity and has constructed plants throughout the country. None are powered by fossil fuels. Australia opted instead for wind power, building up more than enough capacity to power, indirectly, all of the country's desalination plants.

Public-private Partnerships

Building a desalination plant is still a capital-intensive business that many countries cannot afford. Recognizing an opportunity, private entrepreneurs have developed an innovative business model. Independent water and power producers (IWPP) raise capital, and then build and run the plant themselves under a long-term agreement guaranteeing that the local government will buy the output over 20 to 30 years. Governments that cannot afford the upfront capital can often afford the regular payments over the life of the agreement.

An example of such a project in the U.S. is the Carlsbad desalination plant currently being built in southern California by Poseidon Resources. Poseidon brought the project to San Diego county, which sits at the end of the water delivery system in California, and therefore has "the greatest need, pays the most for its water and is most at risk in the event of a drought or shortage on the aqueduct," says Peter MacLaggan, senior vice president of California project development for Poseidon. With much of its water coming from outside the region and subject to intense competition, San Diego County saw an advantage to working with Poseidon.

The county has agreed to pay a fixed price, indexed to inflation, for the water it uses, and to pay the cost of the energy consumed by the desalination plant, as long as that cost stays within a preset limit. If the plant exceeds that limit, Poseidon has to eat the additional cost (a strong incentive to maintain high efficiency).

At the beginning, the county will be paying about twice as much for the desalinated water as it does for the water it imports from traditional sources. Based on history, however, the price of imported water is likely to rise significantly. "Over the last 20 years, the imported water rate has gone up an average of 6.4% per year; over the last 10 years, it's doubled," says MacLaggan. So assuming that the price of imported water continues to rise as it has for the past 20 years, and that inflation remains at predicted levels, the price of desalinated water and imported water will be at parity by 2025. After that, San Diego County will save money on the desalinated water it buys from Poseidon.

All of the capital for the Carlsbad project is coming from private investors. Poseidon has raised \$734 million in the bond market, offering investors an average return of 4.85%. The remaining \$168 million is coming from equity investors, including Poseidon itself, who are expecting a return in the low teens over the 30-year life of the project. The higher return compensates the equity investors for the relatively greater risk they are assuming: Since their investment is subordinate to bondholders, equity investors are more likely to lose out if the project fails to realize its projected profit.

Beyond Seawater

A desalination plant can increase the supply of drinking water without ever processing any seawater. It accomplishes this feat by using essentially the same technology to process brackish water (desalinating brackish water typically costs about one-quarter as much as desalinating seawater and uses much less energy).

The U.S. is one of the biggest producers of desalinated brackish water. The International Desalination Association ranks the U.S. as the world's third-largest user of desalination. According to the *Florida Water Resources Journal*, Florida accounts for more than half of the country's desalination, and 85% of the plants in the state process brackish water. In Texas, another major

player in the U.S. market, none of the state's 44 desalination plants treats seawater, according to *The New York Times*.

Typically, brackish water is drawn from underground aquifers, but with the growing use of fracking to produce natural gas, the oil and gas industry is a potentially huge customer of brackish-water desalination. The fracking process uses liquid under high pressure to fracture shale rock, and the water that emerges at the end of the process is very saline. Desalinating this brackish water could play an important role in limiting the environmental harm fracking can cause.

The major challenge in desalinating brackish water: what to do with the brine that is left over. In seawater plants, such as Carlsbad, the concentrated brine is generally diluted with more seawater, to make it safe for marine life, and then returned to the ocean. Since this is not possible inland, one option is to use the salt from the brine for a wide range of industrial purposes, including the production of hydrogen, chlorine and sodium hydroxide by means of electrolysis. China, the world's leading producer of salt, makes extensive use of the brine from desalination plants.

Other challenges to the growth of desalination remain and are being addressed, including pollution caused by chemicals used in the process, thermal pollution from MED and MSF plants, and the potential of harming marine life. But with global corporations like Dow Chemical, BASF and GE looking for ways to solve these problems and continue driving down the costs of desalination; private enterprise partnering with governments worldwide; and the demand for water outpacing the naturally occurring supply, that 15% annual growth rate Bloomberg mentioned looks like a good bet.

Other challenges to the growth of desalination remain and are being addressed, including pollution caused by chemicals used in the process, thermal pollution from MED and MSF plants, and the potential of harming marine life. The bottom line is that the 15% annual growth rate that Bloomberg cited looks like a good bet. Within the current landscape, the demand for water is outpacing the naturally occurring supply, there is a push by global corporations (like Dow Chemical, BASF and GE) to improve on various environmental and cost issues, and private enterprise is increasing its stake. All bode well for the future of the industry.



Growing Food, Growing Problems

Agriculture now produces enough food to feed everyone on Earth. So why are a billion people still going hungry?

Agriculture, it turns out, is at the center of the food, energy and water nexus. It consumes 70% of the earth's fresh water. And a 2012 study by the Food and Agriculture Organization of the United Nations (FAO) puts agriculture's global energy consumption (for the production of synthetic fertilizers and the powering of irrigation systems, farm machinery and distribution) at "30% of the world's available energy."

The environmental costs are also great. Farming contributes 12% to 14% of total greenhouse gas emissions, according to Mariola Kopcinski, global strategic marketing director for FMC Corporation. Fertilizer runoff has created hypoxic dead zones in several areas of the world (the largest, in the Gulf of Mexico, is as big as the state of New Jersey and growing). Soil has been badly degraded in many areas, Sub-Saharan Africa in particular, said Allen Kelly, the dean emeritus of the University of Pennsylvania's School of Veterinary Medicine. And through deforestation and monoculture farming, agriculture is seriously threatening the planet's biodiversity.

Yet despite this massive use — and misuse — of resources, nearly one in eight living around the world are still chronically hungry.

The Problem Is Getting Worse

During the recent Initiative on Global Environmental Leadership (IGEL) Conference on "The Nexus of Energy, Food and Water," the food security panel addressed the serious challenges agriculture faces in the coming decades. Virtually everyone at the conference noted that by 2030, there would be nine

billion people to feed, a nearly 30% increase over today's global population.

This growth in demand coincides with a decline in productivity from the peak years of the Green Revolution. The success of the Green Revolution was due primarily to the efforts of Norman Borlaug, who won a Nobel Prize for his work, and the International Rice Research Institute (IRRI). Together, they came up with highly productive varieties of grain that dramatically increased the food supply in Mexico, India and Southeast Asia. The increase in wheat yield between 1950 and 2004, said Kelly, was a staggering 250%.

But after years of increasing productivity, the impact of the Green Revolution is now waning, just as the demand for food is increasing. The new high-yield varieties Borlaug introduced "require more expensive inputs into seed, fertilizer and irrigation," Kelly explained, and those costs are going up dramatically. Fertilizers are tied to the price of oil, which means the cost of the synthetic fertilizers has been climbing well beyond the reach of many small farmers.

In addition, climate change and poor land management have resulted in drought and growing desertification in some places, rendering irrigation either costly or impossible. The high-yield plant varieties created by Borlaug and IRRI cannot withstand this lack of water nearly as well as indigenous plants, which evolved to survive in dry areas. So, small farmers are increasingly reverting to hardier, but far less productive, crops.

Another unfortunate result of the Green Revolution: the displacement of many small farmers, who could not afford all those expensive inputs from the countryside to the cities. Sparked by the Green Revolution, this trend toward urbanization is

accelerating at unprecedented rates. Fifty years ago, said Kelly, 80% of the world's population was rural and comfortably produced enough food to feed the 20% who lived in cities. By 2050, the situation will have reversed: It is generally predicted that 75% of the world's population will be living in cities by then, relying on the 25% who remain in the country to meet their need for food.

Costs Prove Critical

The cost of that food will be critically important, since much of this shift from rural to urban living involves poor residents of developing countries. Unable to support themselves on the land, these people are moving to the cities where they have to find jobs so that they can buy the food they once grew themselves. The problem is most acute in Sub-Saharan Africa, which has the fastest pace of urbanization in the world and the least ability to employ its growing urban population. According to Sean Fox of the London School of Economics, "Over 60% of Sub-Saharan Africa's urban population lives in slum conditions; the highest level of 'slum incidence' of any major world region."

In China, the problem associated with urbanization is not poverty, but rather the rapid growth of the middle class. The Chinese government is planning to spend \$6.4 trillion over the next decade to move 60% of the country's population to the cities, a senior planning official told Reuters at the end of February. The original plan, which is currently being revisited, calls for the Chinese government to build homes, roads, hospitals and schools for its growing urban population, in the hopes of spawning an affluent consumer class that will help drive the economy and replace the current export-led model, which is not sustainable.

The challenge for agriculture and the environment is that this new middle class is demanding what middle class residents the world over have always demanded: more meat and dairy. And animal agriculture is one of the least efficient modes of farming. Kopcinski notes that animal agriculture alone accounts for 21% of worldwide methane production and consumes "enormous amounts of water and plant resources. If we keep increasing our meat production and dairy production," she added, "it's just not sustainable."

A recent study, published in the journal *Nature*, points out that 35% of crop production is used

to feed animals, "which produces human food indirectly, and much less efficiently, as meat and dairy products." The study distinguishes between animals raised on land that is unsuited for other food production and animals that displace crops normally grown for human consumption. The former, concluded the study's authors, "can add calories and protein to the world and improve economic conditions and food security. However using highly productive croplands to produce animal feed, no matter how efficiently, represents a net drain on the world's potential food supply."

First Step: Reduce Waste

IGEL senior fellow Bernard David noted at the Nexus conference that, "30% to 50% (1.2 to 2 billion tons) of food produced globally never reaches a human stomach." Huge amounts of food is wasted in the U.S. and other developed countries, in restaurants, at retail and in households.

But food insecurity is almost entirely limited to the developing world, where the situation is very different. A 2013 report by the Institution of Mechanical Engineers noted that in less developed countries, food waste takes place not at the end of the supply chain, but toward the beginning: "Inefficient harvesting, inadequate local transportation and poor infrastructure mean that produce is frequently handled inappropriately and stored under unsuitable farm site conditions."

Resources essential to the growing of food are also wasted. The *Nature* study points to two examples. Areas with limited water resources and poor water and land management practices waste precious water through evaporation loss both in the fields and in storage and transport. And in some areas, fertilizer, too, is over-used, wasting a valuable resource, causing nutrient pollution of water and contributing to global warming by releasing nitrous oxide into the atmosphere. This problem is particularly severe in China, Northern India, the U.S. and Western Europe, the study's authors noted.

While reducing all of this waste would certainly help improve food security, it still leaves an enormous gap. The consensus, Kopcinski said, is that by 2050, agricultural production needs to increase by 60% in order to feed the world's population. As the chart shows, reducing waste lowers this estimate by only a small amount.

Solutions Must Be Local

On a global scale, “we produce enough food for all,” notes FAO Director-General José Graziano da Silva. “We have hunger because people cannot buy the food or produce it themselves.” The nature of the problem varies from region to region, which is why, ultimately, approaches to food security must be grounded in local conditions, as well as local culture.

In China, the central government still largely manages the economy. With only 7% of the world’s land but 20% of the world’s population to feed, the Chinese government has clearly decided to pursue industrial agriculture. Using large-scale farming methods that have marginalized China’s 400 million small farmers, the government has ramped up swine and poultry production by 80% in the past decade, Kelly said, often in coastal areas, creating “a huge animal, environmental and human health threat.” Dairy farming, too, has grown dramatically in China. In 1980 the country had virtually no dairy industry. Today, Kelly noted, “they have something like 15 million milking cows.”

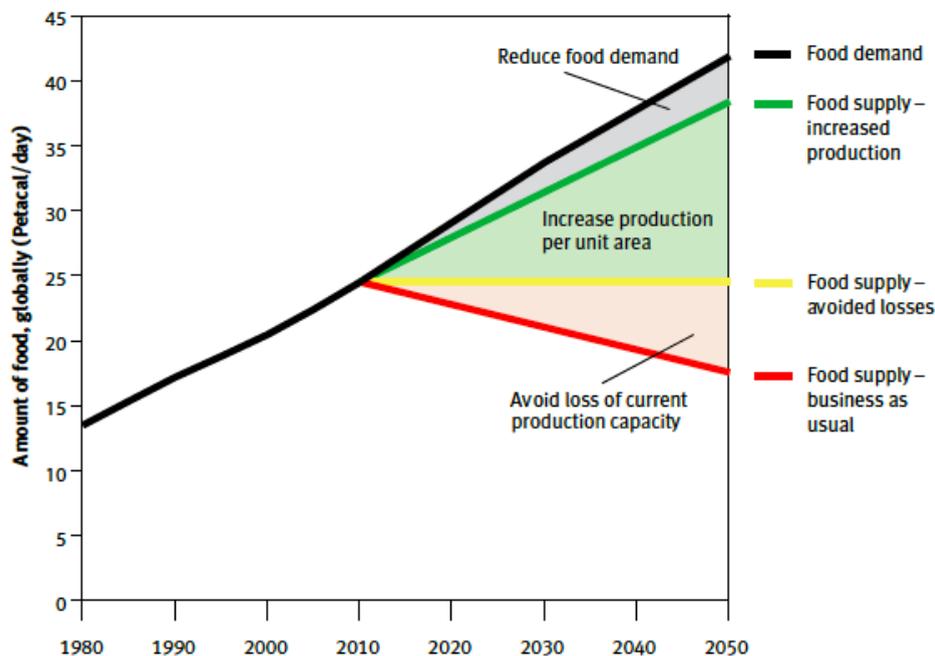
Unlike China, India does have significant land available for agriculture, and as the world’s largest democracy, the government has chosen to target its efforts to small farmers. Much of this effort has focused on boosting milk production through the formation of cooperatives, and today India is the world’s largest milk producer. These efforts are hindered by a poor distribution system, which leads

to a great deal of waste, and by a low yield per cow as compared to world standards.

Slowly but surely, new methods of improving yield per cow are being introduced. According to an article earlier this year in India Knowledge@Wharton, MokshaYug Access (MYA), a Bangalore-based private company, is helping local farmers to improve their yields. “It is tough to convince families to move to MYA because of their long association with the state cooperative, but I am confident that over time, when they see the benefits that their neighbors are enjoying with MYA, they will be more open to this option,” the head of the MYA milk collection center in one village told India K@W.

The countries of Sub-Saharan Africa face the toughest road to food security. The U.S. Department of Agriculture (USDA) noted in 2012 that, “Sub-Saharan Africa is the only region [of 76 studied] projected to have a sizable increase (15.1%) in the number of food-insecure people in the coming decade.” Among the reasons, according to a 2012 report by the FAO, is a lack of access to fertilizer. With badly degraded soil, fertilizer is essential to improving local agriculture, but a combination of market forces has driven up the price of fertilizer in the region until it is now the highest in the world, the FAO reported.

While some see modern large-scale farming — such as the kind practiced in the U.S. — as the answer to many of these problems, the drawbacks of industrial



farming are well-documented. And simply trying to transfer techniques that have worked, however problematically, in this country to other parts of the world is “one of the huge mistakes we have made in the past,” Kelly said.

Some Guiding Principles

While each region must find its own path to food security a few fundamental principles seem clear. A report on the right to food prepared for the United Nations Human Rights Council identified three objectives that must be met to ensure global food security:

- Food must be available to everyone.
- Agricultural practices must be sustainable.
- Agriculture must increase the incomes of small farmers.

The importance of this last objective is critical. As the report stated, “hunger today is mostly attributable not to stocks that are too low or to global supplies unable to meet demand, but to poverty. Increasing the incomes of the poorest is the best way to combat it.”

To meet these objectives, the UN report focused on the benefits of agroecology, which is defined as “both a science and a set of practices.” Using a variety of methods, agroecology increases agricultural productivity in ways that maintain biodiversity; conserve precious resources, including soil fertility; minimize negative impacts on the environment, and increase the resiliency of agriculture in the face of climate change. And agroecology, according to the report, also reduces rural poverty by reducing the need for costly external inputs and by creating jobs.

At the heart of agroecology, said Heather Karsten, a professor of plant science at Pennsylvania State University, is the use of ecological processes and principals. Based on science and practice, agroecology is not dogmatic about what is and is not acceptable. “We’re going to take a lot of ecological approaches,” noted Karsten, “but we’re not going to completely eliminate using pesticides and herbicides. We judiciously target using pesticides when necessary.”

Similarly, agroecology is not opposed to the use of genetically modified organisms (GMOs) that optimize certain traits and increase production. But these technologies are used judiciously only as needed to supplement such ecological approaches

as the integration of livestock and forests into crop production, Karsten added.

Kopcinski noted that there are clear parallels between agroecology and the integrated approach to agriculture that FMC supports. She described it as “looking at the plant in a more holistic way, rather than just trying to treat a disease or insect problem. People realize that it’s not enough to just go and spray pesticides or give enough fertilizer if the plant variety is not right for the climactic conditions, if the soil is not prepared right, if there are not enough micro- and macronutrients and if the soil is not inhabited by all the bacteria, fungi and other organisms that plants need to thrive.”

Agroecology also stresses a holistic approach to agriculture at the societal level, emphasizing the need for improvements in infrastructure, education and access to markets. Helping small farmers become more productive, Kelly said, “requires a very substantial investment in infrastructure, policies that favor small farmers, research and information, and the involvement of the small farmers themselves in deciding what they need.” And it means helping them find ways — often by organizing into larger groups — to become more competitive, especially in urban markets.

The cell phone is already playing a key role, according to the Consultative Group on International Agricultural Research (CGIAR), giving small farmers instant access to agricultural services, information and markets. Cell phones are proliferating throughout much of the developing world. *The New York Times* reported in March that, “Africa has a billion people and 750 million phones, and mobile is growing so fast there that in a few years there will be more phones than people.” With the help of several groups, including the Bill and Melinda Gates Foundation, small farmers are now using their cell phones to discover the best time to plant their seeds, to share new farming methods with each other and to learn the best market in which to sell their produce.

Education is essential to all of these approaches, experts noted. Investment in scientific research has to be reinvigorated, having been neglected when the Green Revolution seemed to have conquered the problem of hunger, and the results of this new research have to be made available to the small farmers. Extension service agents are critically important, but new research shows that what is even more important is the involvement of small

farmers themselves. “Farmer-to-farmer education is often more effective,” said Karsten. “Farmers are more comfortable accepting new practices if they see that their peers have been successful.”

Rikin Gandhi, an American-born software engineer, has created a platform and process called Digital Green, which has proven that showing short, locally produced videos featuring local farmers is highly effective, especially when followed up by facilitated group discussions. According to *The New York Times*, Digital Green has now produced 2,600 videos that have been viewed by 157,000 farmers throughout India, Ethiopia and Ghana. Forty-one percent of these viewers have adopted at least one new practice, and Gandhi is now working with 60 colleagues with plans to reach 10,000 villages by 2015.

Gandhi approaches this work scientifically, trying out new hypotheses that might improve the videos’ effectiveness and carefully tracking the results to evaluate the validity of each hoped-for improvement. This combination of technology, science, education and focus on local farmers embodies the fundamentals of an approach that has the potential to renew agriculture the world over and feed the planet’s growing population.

With hunger already rampant in much of the developing world, the rapid urbanization of the earth’s growing population will tax local agriculture in ways that neither traditional methods nor the technologies of the Green Revolution can address. New community-based, ecology-oriented approaches that harness the power of science, local knowledge and new technologies offer hope for a better future.





The Transportation Nexus: Ethanol Is a 'Food vs. Fuel' Issue

Every year, the U.S. “grows” 13 billion gallons of an American-made fuel — ethanol — and consumes some 40% of the nation’s corn crop in the process (as well as about three gallons of water for every gallon of fuel produced), according to the Food Agriculture Policy Research Institute.

Together, those facts are a key example of what has become known as the nexus of energy, food and water, and a growing awareness of the relationships among them threatens to derail the green reputation of American ethanol production. According to a study by the Swiss Federal Laboratories, “Although biofuels can allow the reduction of fossil fuel use and of greenhouse gas emissions, they often shift environmental burdens towards land use-related impacts.”

Corn ethanol is a polarizing resource. Despite some emissions benefits when burned, it has inspired angry campaigns by green nonprofit organizations. “Corn ethanol has not just been a disaster for consumers, most farmers and taxpayers; it’s also been a disaster for the environment,” the Environmental Working Group noted.

The Energy Balance

Corn is a popular crop. It has many uses besides directly feeding people and making ethanol. A third of the crop becomes livestock fodder, and 13% of U.S. production gets exported. But is corn ethanol, on a well-to-wheels basis, sustainable? Does it not only result in a net energy loss but also drive up the cost of one of the world’s most important food staples? The debate has grown more intense with rising corn prices, which critics say are caused by the diversion of almost half the crop into fuel

production.

Supporters claim a major carbon benefit for ethanol. According to the Renewable Fuels Association trade group, “In 2012, the 13.2 billion gallons of ethanol produced reduced greenhouse gas emissions from on-road vehicles by 33.4 million tons. That’s equivalent to removing 5.2 million cars and pickups from the road for one year.” And a study published in the *Yale Journal of Industrial Ecology* claimed that the greenhouse gas benefit of corn ethanol compared to gasoline was 48% to 59%. The Argonne National Laboratory, in a 2007 study, found a lifecycle greenhouse reduction of 19% to 52%.

Ethanol boosters tout a 30% reduction in tailpipe carbon monoxide emissions, and a 50% cut in cancer-causing particulate matter, compared to gasoline. It’s also an oxygenator and emissions neutralizer in gasoline. And they claim a positive energy balance, yielding almost twice as much energy as goes into production. Sharply contesting that are scientists David Pimentel of Cornell University and Tad Patzek of the University of California at Berkeley, who said in a 2005 study that overall, corn ethanol uses 29% more fossil-fuel energy in production than the fuel produced.

Ethanol does have some positive benefits, but the drawbacks are big, too, according to Kent Smetters, a professor of business economics and public policy at Wharton. “Even with an expanded supply of corn, it is likely that corn prices are quite a bit higher and people are being harmed, especially in developing countries,” Smetters said.

Beyond higher prices for food, it’s also not likely the planet is able to accommodate increasing demands for food, fuel and water. According to the “Understanding the Nexus” paper prepared for a

UN Bonn 2011 Conference: The Water, Energy and Food Security Nexus, “Unless there are significant changes to the way that we produce and consume, agricultural production will have to increase by about 70% by 2050 and about 50% more primary energy has to be made available by 2035. Such increases would have far-reaching implications for water and land resources.”

Looking at Land

Steve Hamburg, chief scientist at the Environmental Defense Fund, said the challenge is not simply whether there is “enough land to scale up both agriculture and ethanol production without impacting natural ecosystems.” There is also the long-term context — will there be “enough food for the increased population we will have in 2050.” Future challenges include meeting increased dietary goals as people move out of poverty, given the existing water stress facing the planet. “The key is how efficiently we use the land. There’s no simple good or bad answer, but if we end up clearing large amounts of land to make more ethanol, it’s categorically bad.”

Jerry Melillo, senior scientist at the Marine Biological Laboratories and chairman of the federal National Climate Assessment, agreed that scaling up a global biofuels program would be daunting. “We have 148 million square kilometers of land on the planet, with 16 million of them in crops,” he said. “Building a worldwide ethanol network would involve at least doubling that.”

In looking at ethanol the conversation at some point usually turns to its effect on food prices. Why did the price of food basics jump between 2006 and 2008? A World Bank report, “Placing the 2006/08 Commodity Price Boom into Perspective,” finds a variety of causes, diversion of food crops into biofuel production among them. But it also cites adverse weather conditions and government policies (including export bans and high taxes) as factors in reducing food stocks to levels not seen since the early 1970s.

Another paper, from the University of California’s Giannini Foundation of Agricultural Economics, concluded that ethanol sometimes doesn’t get credit for its positive contribution. While biofuels have raised food prices, the net market impact “is unsettled,” the report noted. “High food prices have been accompanied by record high oil prices, and while biofuels have been blamed for exacerbating the former, they have not been credited with

mitigating the latter.” As the paper pointed out, high fuel prices push up the cost of running tractors, using petroleum-based fertilizers and transporting agricultural products. For growing, harvesting and delivering cotton, corn, soybeans and wheat, fuel made up from 10% to almost 35% of operating costs in 2009, the California study said (about 14% for corn.) If biofuels helped reduce operating cost by making gasoline and diesel cheaper, that should be factored into food vs. fuel equations.

Still, the California researchers concluded that, using 2007 data, “ethanol raised corn prices at least 18% and perhaps as much as 39%, depending on elasticity assumptions.” Obviously there were other factors, but biofuels were responsible for 25% to 60% of recent corn price increases, they said.

Sustainable or not, increased ethanol output is enshrined in the relatively unpopular approval of higher ethanol content in gasoline and in the federal Renewable Fuel Standard (RFS), which sets a 36 billion-gallon target for biofuel production by 2022.

The Cellulosic Challenge

Dave Juday, an economist specializing in agriculture and conservation issues, thinks it’s time to rethink the RFS. He pointed out that the U.S. corn supply is down 1.3 billion bushels from 2007 projections, and demand for motor fuels has declined. But a different kind of ethanol — cellulosic ethanol, made from the inedible parts of plants — offers a way out of the “food vs. fuel” dilemma. It is generally thought to have a much more positive energy balance than the corn form, and because it can be produced from grasses and other plants there’s no “food vs. fuel” conflict.

John Paul MacDuffie, a professor of management at Wharton, said the best way to make ethanol is “from non-food sources, such as switchgrass, where there have been promising developments on developing enzymes to break down plants into sugars that can be converted to fuel.”

Cellulosic ethanol, which can be made from plants grown on abandoned or degraded lands, has few obvious drawbacks. But Juday pointed out that the technology needed to commercialize the fuel (made from the fibrous parts of plants) has not materialized as predicted.

The RFS mandates the production of 16 billion gallons by 2022, but so far only a trickle of that fuel is being produced. The result, reported *The New*

York Times, is that the Environmental Protection Agency “has had little choice but to repeatedly waive nearly all of the cellulosic requirements, but this has led to bitter complaints from the refiners, who say they are still required to use small quantities of a fuel that does not exist or face fines.” The cellulosic requirement for 2013 was reduced to just 14 million gallons early in the year.

The potential of cellulosic ethanol remains impressive. A 2013 study, led by Ilya Gelfand of Michigan State University and published in *Nature*, concluded that a mix of perennial grasses and herbs would make the most sustainable cellulosic biofuel, but not without challenges. The key: growing a native crop (poplar trees and alfalfa were two under study) with minimal care needs on “marginal” land not currently used for producing crops. Under that scenario, the CO₂ reduction could be twice that of corn ethanol, the study said.

Other research showed that 5.5 billion gallons of cellulosic ethanol could be produced from 27 million acres of unproductive land in just 10 Midwestern states. Offsetting gasoline or diesel with that ethanol would cut greenhouse emissions by 44 million metric tons annually.

But for now, Juday noted, “There’s no infrastructure for cellulosic.” Even with a technology breakthrough for switchgrass — a fast-growing plant seen as a favorite for producing the fuel — big questions remain about providing the needed seed, planters, pesticides, harvesters, bailers and railcars. “If we add 50 million acres of switchgrass, where will it come from?” asked Juday. “Crop land? Grazing land? Forested land?” He added that a moderate amount of starch-based ethanol will “always have a place in the fuel market as an oxygenate/octane enhancer [15% blends are now permitted in gasoline by the Environmental Protection Agency (EPA)], but the RFS is highly distortive and cellulosic ethanol technology is years off.”

The Union of Concerned Scientists pointed out that the vacuum in available cellulosic ethanol has led federal officials to modify the RFS to allow increasing amounts of both biodiesel from soybeans and ethanol from sugarcane, both of which the group sees as “food vs. fuel” issues. “If the EPA keeps substituting food-based fuels for the delayed cellulosic biofuel, we will see a huge expansion of biodiesel and sugarcane ethanol production that will lead to increased deforestation in the tropics and continued pressure on global food supplies.”

The Palm Oil Dilemma

A prime example of how that can happen is the unsustainable palm oil biofuel production in Indonesia and other countries, which is rapidly clearing virgin forests in Southeast Asia (see “Deforestation in Southeast Asia: The Future is Being Decided in Indonesia,” from Knowledge@Wharton, which is part of a special report: *The Pathways to Sustainability in Emerging Markets*). The food vs. fuel debate is “sometimes more like a ‘rainforest vs. fuel’ debate: deforestation due to palm oil in Indonesia is really troubling, said Arthur van Benthem, professor of business economics and public policy at Wharton.

Van Benthem noted that some corporations, under pressure from activist groups and consumers, are also becoming troubled by palm oil. He pointed out that, in 2009, Unilever, then the world’s largest user of palm oil, canceled contracts for edible oil from Indonesia’s largest producer, Sinar Mas Agro Resources and Technology, because of ongoing rainforest destruction. The ban was in effect, Reuters reported, until Sinar Mas could “give proof that none of its plantations was contributing to the destruction of rainforests.” In 2011, the *Jakarta Post* reported, Unilever (which has pledged to buy only sustainably produced oil by 2015) began buying palm oil from the company again, following promises that it would adopt green production methods. Both Nestlé and Burger King also canceled contracts with Sinar Mas.

This all makes forward progress on commercial-level cellulosic that much more important, proponents say. Despite the slow start, there is progress. INEOS’ Indian River BioEnergy Center in Florida, for example, is slated to begin producing eight million gallons of cellulosic ethanol annually, as well as six megawatts of electricity, from agricultural waste and other sources. But the Christian Science Monitor estimated that cellulosic production in 2022 is still likely to be closer to three billion gallons than the 2022 RFS target of 16 billion.

A More Sustainable Biofuel

But not all current ethanol production has a bad energy balance, and more sustainable fuel sources will be badly needed. That was made clear at the “Nexus of Energy, Food and Water,” workshop sponsored by the Initiative for Global Environmental Leadership (IGEL) at Wharton last March. J. Ashley Nixon, NGO and stakeholder relations manager

at Shell Oil, noted that a rising world population that could reach some nine billion by 2050 is a major stressor. "We could see a doubling of energy demand while carbon dioxide emissions must be half of today's, and there is a need for three times more energy from renewable sources." Water demand could rise 30% by 2030 while food demand grows 50%.

In 2011, Shell and partner Cosan, launched a \$2 billion venture, Raízen, to produce ethanol from sugarcane in Brazil. Biofuels are likely to be 30% or more of Brazil's transportation fuel mix by 2030, and Raízen alone can meet almost 9% of the country's ethanol demand. Such cane ethanol has been blended into Brazilian gasoline in 10% to 25% concentrations since 1976. "The most widespread use of ethanol is in Brazil, and close to 100% of the vehicles on the road are 'flex-fuel,' able to run on ethanol or gasoline," MacDuffie said. "Ethanol is widely available and affordable, and the fuel is an important sector for the Brazilian economy."

Brazil is the largest sugarcane producer in the world, and half of its crop goes to producing ethanol. According to Triple Pundit, "Brazil's energy policy is one cog in the machine that has turned Brazil into an economic darling over the past decade. The country of over 190 million has been relatively energy independent, it became a creditor nation for the first time last year; and has tamed inflation while maintaining a respectable growth rate."

Sugarcane ethanol is more efficient than corn ethanol because growing cane absorbs copious amounts of carbon dioxide, and waste parts of the cane plant can be used as an energy source to fuel the process. According to Shell, cane ethanol produces 70% less carbon dioxide than gasoline "when the cultivation and production processes are taken into account." *Fast Company* reported that for every fossil fuel unit expended to make cane ethanol, eight units of energy are produced. Sugarcane cultivation also has almost doubled the ethanol output per acre of corn.

Since 2003, Unica noted, the use of ethanol in Brazil has avoided over 103 million tons of carbon dioxide emissions vs. gasoline use. The favorable energy balance is one reason the EPA includes Brazilian sugarcane ethanol as one of the acceptable "advanced biofuels" (along with soybean biodiesel and cellulosic) that is part of a 2.75 billion-gallon quota that was retained for 2013.

There are some issues with Brazilian sugarcane, however, since it is grown in the *cerrado*, a savanna area between the coast and Amazon region that is home to many rare native plants. And is Brazilian sugarcane a "food vs. fuel" issue, as the Union of Concerned Scientists implied? Maybe not. "I've never heard of Brazil having shortages of sugar for use as a sweetener," MacDuffie said. And a World Bank article, "Note on Rising Food Prices," stated that "Brazilian ethanol production from sugarcane has not contributed appreciably to the recent increase in food commodities prices because Brazilian sugarcane production has increased rapidly and sugar exports have nearly tripled since 2000.... The increase in cane production has been large enough to allow sugar production to increase from 17.1 million tons in 2000 to 32.1 million tons in 2007 and exports to increase from 7.7 million tons to 20.6 million tons."

Colin A. Carter, a professor of agricultural and resource economics at the University of California at Davis, takes a free-market position in arguing that Brazil's success is at least partly the result of its absence of any RFS-type quotas. Free market advocates praise "flexible policies that allow the market to determine whether sugar should be sold on the sugar market or be converted to fuel." And they recommend that at least some of the U.S. RFS be waived, "thereby directing corn back to the marketplace."

But the U.S. quotas also have some flexibility options. And luckily so, because market realities have led to them being reduced or waived. Given these setbacks, it's difficult to see how production could be ramped up to meet the overall goal of 36 billion gallons of biofuels by 2022.

The Real Issue is Oil

As a domestic fuel, corn ethanol has its defenders. The Fuel Freedom Foundation, for instance, points to the \$780 billion spent annually by the U.S. for oil products, and the \$300 billion of that spent on foreign oil — representing more than 50% of the trade deficit.

According to Eyal Aronoff, the former software executive who is a co-founder of the Fuel Freedom Foundation, "The real issue isn't food vs. fuel, it's food vs. gasoline. As the price of gasoline goes down, everything goes down." He said that because ethanol is added to mainstream pump fuel (in

10% and 15% concentrations), its price is closely intertwined with that of gasoline. The value of the corn in a gallon of gas is only 40 cents. "There are many other costs beyond the commodity price," he noted.

Carl Pope, the longtime executive director of the Sierra Club and now an energy consultant, said that the "food vs. fuel" controversy is something of a diversion from the main issue, which is fossil fuels. What has driven up food prices in India (where corn is not widely consumed) is the cost of diesel fuel, he pointed out. "It costs just \$400 to \$600 to fill a container with corn in the Midwest, but \$4,000 to \$5,000 to ship that corn to California because of the transportation costs," Pope said. "When oil goes up, food goes up."

Higher gas and diesel prices routinely drive up food costs, Pope added, because of fuel's intensive use in today's highly mechanized farming. Petroleum is also a key component in pesticides and fertilizers. "We ought to label food with its energy content," he said.

Both Pope and Aronoff recommended increased use of domestically produced fuel, including natural gas, ethanol and methanol (as well the use of as electric cars), to push down petroleum use and therefore its price. "It's striking how rapidly fuel prices drop as consumption declines," Pope said. "If we use 90 million barrels of oil a day worldwide, the price is \$100 a barrel. If it's 80 million, the price is just \$30."

Cheaper oil, Pope noted, would make it uneconomical to produce unconventional oil, some of which is environmentally damaging — such as Canadian tar sands, Arctic oil and Venezuelan heavy crude. "Sixty percent of the world's oil carbon does not come to market under that scenario," he said. Pope added that it's unlikely that the availability of cheaper oil would push consumption dramatically higher.

The Renewable Fuels Association, a Washington-based trade group for ethanol producers, also suggested taking a holistic view. According to Bob Dinneen, the association's president and CEO, a fair assessment of the environmental impacts of renewable fuels must take into account

"comparisons to the impacts associated with the use of petroleum fuels ... it is inappropriate to examine the environmental effects of the RFS without simultaneously examining the effects of not having the RFS."

Dinneen accused ethanol's Congressional critics of "missing the significant environmental and public health consequences of increased petroleum production and use in the absence of ethanol and the RFS."

A 2012 paper by Paul Thompson of Michigan State in *Agriculture*, titled, "The Agricultural Ethics of Biofuels: The Food vs. Fuel Debate," concluded that the fuels "could be a positive force in addressing the circumstances that cause hunger among the roughly 80% of the world's poorest people whose food entitlement is closely tied to agricultural production." If next-generation biofuels could be developed with the farming systems of poor producers in mind, they could "have a beneficial impact on poor producers' economic return."

Ethanol has passionate advocates, and equally passionate detractors. In 2013, it's the latter that are being heard more clearly in Washington, signaling a change in political fortunes for this long-subsidized product. And the "food vs. fuel" controversy is one of the more potent weapons in the critics' arsenal.

Corn ethanol has clear emissions advantages when it's burned in a vehicle, observers noted, but the lifecycle analysis of overall performance is murkier. Cellulosic ethanol continues to show great promise as an efficient alternative that does not displace crops. But despite the high hopes of federal officials, it hasn't proceeded to the commercial stage as quickly as anticipated. Ethanol got a clear boost from the 15% blends now legal for newer cars, but that decision was heavily criticized as injurious to engines by automakers and others.

For ethanol in general, the road ahead is full of roadblocks and possible dead ends, but with so much technology still under development it's too early to write it off as an effective energy solution.

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