Future Fuels From Forests

By Mike Frost

Unit Overview:
Fossils fuels are a limited resource that will be extremely scarce in the foreseeable future. In addition to dwindling supplies, fossil fuels have a significant environmental impact. Science and Math teachers must encourage students to choose careers and provide the skills necessary to enter fields that will explore and develop alternative energy sources for the growing world demand. The following unit is designed to integrate current curriculum on photosynthesis with ethanol production. Ethanol production and use is a current technology that is expanding rapidly in the global market. Many countries and independent companies are working diligently trying to develop technology that will maximize ethanol production from biomass waste or low quality crops. Ethanol may not be the long term solution to dependence on oil but it may be a stepping stone in the right direction.

Goal:
The goal is to educate students about ethanol production for an alternative fuel source as well as the positive and negative implications of using different biomass sources for the production of ethanol.

Target Subject: Biology

Target Grade: High School grades 9, 10, and 11

Connection to Curriculum:
The goal of the unit is to connect biology curriculum on photosynthesis to the current global topic of ethanol production.

Teaching and Learning Objectives:

- Students will be able to understand the connection between the products of photosynthesis and plant metabolism and ethanol production.
- Students will be able to list energy and environmental reasons why corn should not be used for ethanol production based on a life cycle assessment of various sources of biomass.
- Students can explain an example of a biomass that would have a low to no carbon footprint.
- Students will be able to identify common tree species of Wisconsin forest
- Students will be able to measure the carbon content of the trees they identified.

Resources:

1. Bourne, Joel K. Jr. Green Dreams in National Geographic Magazine. October, 2007
2. Department of Natural resources Madison, Wisconsin, Bureau of Forestry (1990) Forest Trees of Wisconsin.
3. Fargione, Joseph, et al. (2008). Land Clearing and the Biofuel Carbon Debt. www.scienceexpress.org
4. Grunwald, Michael. *The Clean Energy Scam* in Time Magazine. March 27, 2008.

5. U.S. Dept of Energy. (2006). *Breaking the Biological Barriers to Cellulosic Ethanol: A Joint Research Agenda* resulting form the Biomass to Biofuels Workshop, Dec. 7-9, 2005, Rockville, MD.

<u>Content Benchmarks:</u>

Science Standards:

1. A.10.1 a. Given an event, issue, or problem in the natural or designed world, apply the science theme(s) associated with it. Examples: pollution- apply the themes: interactions, change, and evidence; new technologies such as hybrid cars or hydrogen fuel cells - apply the themes: form and function, models, and systems…
2. C.10.1 a When studying science content: Ask testable questions suggested by current social issues, scientific literature, or observations of phenomena.

3. C.10.3 e. Use the metric system (SI: System International units).

4. C.10.4 a. During investigations choose the best-data collection procedures.

5. F.10. 9 b. Matter, Energy, and Organization in Living Systems: Understand the sun is one of the primary energy sources for all life on earth.

6. F.10. 9 e. Matter, Energy, and Organization in Living Systems: Explain how energy is stored in food and how energy is released by using the themes of science. Examples: change - energy conversions in photosynthesis and respiration; equilibrium - photosynthesis/respiration; models - energy pyramid, order - ten percent energy transfer rule...

Math Standards:

A: The student uses a variety of strategies in the problem-solving process.

M-F4: Reads and interprets data in simple graphs, charts, complex graphs, tables, and plots.

M-F8: Understands faulty arguments, common errors, and misleading presentation of data.

Classroom/Field Activities:

All handouts and readings in the following lessons are provided

Day 1: Lecture and notes on photosynthesis using the provided PowerPoint presentation on photosynthesis.

Day 2: Finish lecture on photosynthesis and have students take the quiz provided. Quiz is at the end of the photosynthesis PowerPoint

Day 3: Introduce ethanol production using an anticipatory set. Use the list provided of the products that corn is used to manufacture and set out ten items. Try to use a wide variety. Ask the students what the ten items have in common. The point is to emphasize the significance of corn in manufacturing consumer goods and it is not a viable ethanol source.

After the anticipatory set, teach the information on fossil fuel consumption rates and ethanol production. The material is located in the PowerPoint photosynthesis-Ethanol presentation.

Day 4: Use the PowerPoint slides to teach about other sources of biomass for ethanol production as well as the economic and environmental benefits and consequences of using a variety of ethanol producing sources.

Handout the readings Green Dreams from National Geographic and Time magazines The Clean Energy Scam and have students complete the article response handout for the two articles.

Day 5: Handout and explain the template for creating a field guide to the common trees of Wisconsin. Demonstrate and model how to use the field guide “Forest Trees of Wisconsin”.

Handout and explain the activity “The Carbon in Trees”.

Students will be required identify, photograph, and calculate the carbon content in kilograms and pounds for at least seven trees for their field guide.

Day 6 and 7: Students will have two full class periods to complete the tree identification data collection.

Day 8: Provide class time and resources (field guides, internet, etc.) for students to assemble the information and pictures for completion of the field guide. Build in extra time; it may take more than one day for assembly.

NAME___________________________
PERIOD________
DATE__________

ARTICLE RESPONSE

1. Title and author:

2. Using specific examples from the article, describe the significance the article has on your life and lifestyle:

3. Summarize and list important information and facts about the article:

4. Describe your personal reaction to a specific item from the article. Include how your knowledge about the topic may have changed after reading the article.

NATIONAL GEOGRAPHIC MAGAZINE
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Green Dreams

Making fuel from crops could be good for the planet—after a breakthrough or two.

By Joel K. Bourne, Jr.
National Geographic Staff

When Dario Franchitti steered his sleek, 670-horsepower, orange-and-black Indy car to victory at this year's Indianapolis 500, the ebullient Scotsman chalked up an odd footnote in sports history. He became the first driver ever to win the iconic American auto race on pure ethanol—the gin-clear, high-octane corn hooch that supporters from midwestern farmers to high-ranking politicians hope will soon replace gasoline as America's favorite motor fuel.

Indy's switch back to the old bootlegger's friend is just one indicator of the mad rush to biofuels, homegrown gasoline and diesel substitutes made from crops like corn, soybeans, and sugarcane. Proponents say such renewable fuels could light a fire under our moribund rural economy, help extract us from our sticky dependence on the Middle East, and—best of all—cut our ballooning emissions of carbon dioxide. Unlike the ancient carbon unlocked by the burning of fossil fuels, which is driving up Earth's thermostat by the minute, the carbon in biofuels comes from the atmosphere, captured by plants during the growing season. In theory, burning a tank of ethanol could make driving even an Indy car carbon neutral.

The operative word is "could." Biofuels as currently rendered in the U.S. are doing great things for some farmers and for agricultural giants like Archer Daniels Midland and Cargill, but little for the environment. Corn requires large doses of herbicide and nitrogen fertilizer and can cause more soil erosion than any other crop. And producing corn ethanol consumes just about as much fossil fuel as the ethanol itself replaces. Biodiesel from soybeans fares only slightly better. Environmentalists also fear that rising prices for both crops will push farmers to plow up some 35 million acres (14 million hectares) of marginal farmland now set aside for soil and wildlife conservation, potentially releasing even more carbon bound in the fallow fields.

The boom has already pushed corn prices to heights not seen in years, spurring U.S. growers to plant the largest crop since World War II. Around a fifth of the harvest will be brewed into ethanol—more than double the amount only five years ago. Yet such is the thirst for gasoline among SUV-loving Americans that even if we turned our entire corn and soybean crops into biofuels, they would replace just 12 percent of our gasoline and a paltry 6 percent of our diesel, while squeezing supplies of corn- and soy-fattened beef, pork, and poultry. Not to mention Corn Flakes.

Still, the prospect of amber waves of home-grown energy crops is too seductive to ignore, especially given the example of Brazil. Thirty years after launching a crash program to replace gasoline with ethanol from sugarcane, Brazil announced last year that thanks to ethanol and rising domestic oil production, it had weaned itself off imported oil. Investors, led by superstar CEOs Richard Branson of Virgin Atlantic and Vinod Khosla of Sun Microsystems fame, have bought into the vision, sinking more than 70 billion dollars into renewable energy companies. The U.S. government has ponied up hefty ethanol subsidies, and President Bush has proposed over 200 million dollars for research, with a goal of replacing 15 percent of our projected gasoline use with ethanol and other fuels by 2017.

"We can create ethanol in an incredibly dumb way," says Nathanael Greene, a senior researcher with the Natural Resources Defense Council. "But there are many pathways that get us a future full of wildlife, soil carbon, and across-the-board benefits." The key, Greene and others say, is to figure out how to make fuel from plant material other than food: cornstalks, prairie grasses, fast-growing trees, or even algae. That approach, combined with more efficient vehicles and communities, says Greene, "could eliminate our demand for gasoline by 2050." A century ago, Henry Ford's first car ran on alcohol, while Rudolf Diesel fired his namesake engine with peanut oil. But both inventors soon discovered that "rock oil," when slightly refined, held far more bang per gallon than plant fuel, and was cheap to boot. Oil soon left plant fuels in the dust. Only in periods of scarcity—like the OPEC oil embargo of 1973—did the U.S. and other countries turn back to ethanol, mixing it into gasoline to stretch supplies.

It wasn't until 2000 that fuel alcohol staged a major comeback, largely as an additive in less polluting gasoline blends. For years, ethanol producers had enjoyed heavy subsidies and protective tariffs on imports, while Archer Daniels Midland, the largest U.S. ethanol producer, advocated mixing ethanol into motor fuel. But ethanol ran into stiff competition with the oil industry's own additive, methyl tertiary-butyl ether (MTBE).

Then MTBE, a suspected cancer agent, began turning up in aquifers, prompting many states to ban the chemical and suddenly creating a two-billion-gallon market for ethanol. Recently, with the Middle East in turmoil and oil security once again a hot issue, Congress gave the ethanol industry another boost, extending the tax credits and tariffs while requiring that 7.5 billion gallons (28 billion liters) of the nation's fuel come from ethanol or biodiesel by 2012. (That figure could rise to 60 billion gallons, 227 billion liters, by 2030 if some senators have their way.) The biofuels boom was on.

Ethanol enthusiasts point out that the oil industry has also reaped huge subsidies for decades, including billions of dollars a year in tax breaks, as well as tens of billions of dollars annually to defend oil fields in the Middle East—even before the war in Iraq. Not to mention the untallied costs to health and the environment of pollution from cars, trucks, and the oil industry itself. And while oil subsidies flow into the hands of the wealthiest companies in the world, ethanol subsidies are fueling a renaissance in small heartland towns with names like Wahoo, Nebraska.

By this summer, with Nebraska's 16 ethanol plants gearing up to consume a third of the state's crop, corn prices had doubled, briefly topping four dollars a bushel, and growers were looking forward to the best profits in memory. "This is the first year I've planted all corn and no beans," says Roger Harders as he finishes lunch at the Wigwam Café in Wahoo. He also has cattle that this year will eat a lot more grass than four-dollar corn. "You're almost tempted to get out of the cattle business and sell your corn outright."

Gary Rasmussen, co-owner of the local Case-IH implement dealership, sold ten new corn harvesters at upwards of $200,000 each from December through February, twice as many as usual, and his tractor sales are up as well.

A computer screen showing the latest corn prices is on prominent display on the sales floor. "Anytime you see a surge in commodity markets, you see a brighter future," says Rasmussen. "Ethanol is going to be a real driver." Despite the boom, it's hard to fill up with ethanol in the U.S. It's still mainly a gasoline additive. Only about 1,200 stations scattered mostly across the corn belt sell ethanol, in the form of E85 (85 percent ethanol, 15 percent gas), which can be burned only in specially designed engines. Ethanol delivers 30 percent fewer miles a gallon than gasoline, but at around $2.80 a gallon in the heartland, it is competitive with $3.20-a-gallon gas. Since the U.S. has no major pipelines for ethanol, transportation by truck, rail, or barge drives up the price elsewhere. But more ethanol plants are popping up all the time. Christine Wietzki, a former farm kid from western Nebraska, is technical manager for one of the newest and most advanced ethanol plants in the country, the E3 BioFuels plant in tiny Mead, Nebraska, population 564. She's spent much of her young career turning food into fuel and believes it's a good deal all around. "If we don't have to export corn and can use it to get off foreign oil, that's fantastic," she says. In a cold spring downpour, Wietzki shows off the plant, a cluster of new white buildings, tanks, and a grain bin rising from thick gray mud next to a pungent, 30,000-cow feedlot.

Much of what happens in its tanks and pipes is typical of any large distillery—after all, people have been turning grain into alcohol for eons. The corn is ground, mixed with water, and heated; added enzymes convert the starch into sugars. In a fermentation tank, yeast gradually turns the sugars into alcohol, which is sepa srated from the water by distillation. The leftover, known as distillers' grains, is fed to the cows, and some of the wastewater, high in nitrogen, is applied to fields as a fertilizer.

The process also gives off large amounts of carbon dioxide, and that's where ethanol's green label starts to brown. Most ethanol plants burn natural gas or, increasingly, coal to create the steam that drives the distillation, adding fossil- fuel emissions to the carbon dioxide emitted by the yeast. Growing the corn also requires nitrogen fertilizer, made with natural gas, and heavy use of diesel farm machinery. Some studies of the energy balance of corn ethanol—the amount of fossil energy needed to make ethanol versus the energy it produces—suggest that ethanol is a loser's game, requiring more carbon-emitting fossil fuel than it displaces. Others give it a slight advantage. But however the accounting is done, corn ethanol is no greenhouse panacea.

"Biofuels are a total waste and misleading us from getting at what we really need to do: conservation," says Cornell University's David Pimentel, who is one of ethanol's harshest critics. "This is a threat, not a service. Many people are seeing this as a boondoggle." But Wietzki and her colleagues in Mead think they can do better. They hope to improve the energy balance and greenhouse gas benefits of ethanol by creating a closed-loop system—which is where those cows come in. They plan to fire their boilers with methane from two giant four-million-gallon biodigesters fed with cattle manure from the feedlot next door—in effect using biogas to make biofuel. The increased efficiency, she says, isn't only good for the environment, it's also good business, especially if the price of corn keeps rising or oil drops below $45 a barrel or so, the lowest price at which ethanol backers say the fuel can compete with gasoline in the U.S. "The last people standing," Wietzki says, "will be highly efficient producers like us."

It's easy to lose faith in biofuels if corn ethanol is all you know. A more encouraging picture unfolds some 5,500 miles southeast of Mead, where the millions of drivers of São Paulo, Brazil, spend hours a day jammed to a standstill in eight lanes of traffic, their engines, if not their tempers, idling happily on **álcool** from Brazil's sprawling sugar belt. The country had been burning some ethanol in its vehicles since the 1920s, but by the 1970s it was importing 75 percent of its oil. When the OPEC oil embargo crippled the nation's economy, Brazil's dictator at the time—Gen. Ernesto Geisel—decided to kick the country's oil habit. The general heavily subsidized and financed new ethanol plants, directed the state-owned oil company, Petrobras, to install ethanol tanks and pumps around the country, and offered tax incentives to Brazilian carmakers to crank out cars designed to burn straight ethanol. By the mid-1980s, nearly all the cars sold in Brazil ran exclusively on álcool.

Formula One-loving Brazilian drivers embraced the cars, especially since pure ethanol has an octane rating of around 113. It burns best at much higher compression than gasoline, allowing alcohol engines to crank out more power. Best of all, the government subsidies made it significantly cheaper. Not that ethanol didn't hit a few bumps in the road. By the early 1990s, low oil prices led the government to phase out the subsidies, and high sugar prices left the sugar mills, or *usinas,* with no incentive to produce the fuel. Millions of alcohol car drivers like Roger Guilherme, now a supervising engineer at Volkswagen-Brazil, were left high and dry.

"Guys like me had to wait in long lines two hours or more to fuel up," Guilherme says in his office at the massive Volkswagen plant in São Bernardo do Campo. "Consumers lost confidence in the alcohol program." A decade later when oil prices started to rise, Brazilians wanted to burn alcohol again, but given their past experience, they didn't want to be wedded to it. So Guilherme's bosses gave him a challenge: Find an inexpensive way for one car to burn both fuels. Guilherme's team worked with engineers at Magneti Marelli, which supplies fuel systems to Volkswagen, to write new software for the engine's electronic control unit that could automatically adjust the air-fuel ratio and spark advance for any mixture of gasoline and alcohol. Volkswagen introduced Brazil's first TotalFlex vehicle in 2003, modifying a small soccer ball of a commuter car called the Gol, which means—you guessed it—"goal!" It was an instant hit, and soon every other carmaker in Brazil followed suit. Today, nearly 85 percent of cars sold in Brazil are flex: small, sporty designs that zip around the lumbering, diesel-belching trucks in São Paulo. You can even get a flex Transporter—the beloved loaf-shaped VW van, still made here. With a liter of alcohol running an average of one Brazilian real cheaper than gasoline at the pump, most flex cars haven't burned gas in years. Sugarcane, not engine technology, is the real key to Brazil's ethanol boom. The sweet, fast-growing tropical grass has been a staple export for the country since the 1500s. Unlike corn, in which the starch in the kernel has to be broken down into sugars with expensive enzymes before it can be fermented, the entire sugarcane stalk is already 20 percent sugar—and it starts to ferment almost as soon as it's cut. Cane yields 600 to 800 gallons (2,300 to 3,000 liters) of ethanol an acre, more than twice as much as corn.

Usina São Martinho, one of the largest sugar mills and ethanol distilleries in the world, sits in the heart of the emerald desert, as one São Paulo columnist has dubbed Brazil's prime sugarcane region in central São Paulo state. The rolling fields are carpeted with cane for as far as the eye can see. Each year the mammoth plant turns seven million tons of cane into 300 million liters of ethanol for Brazilian cars and 500,000 tons of sugar, bound mainly for Saudi Arabia. To meet growing demand for ethanol both here and abroad, the company is also building a three-million-ton unit—exclusively for ethanol—in the rapidly expanding cane fields of Goiás state.

Growers in the emerald desert can get seven harvests from their fields before replanting, and the distilleries recycle their wastewater into fertilizer. Like most of Brazil's usinas, São Martinho consumes no fossil fuel or electricity from the grid; for heat and power it burns cane waste, known as **bagasse,** typically generating a slight surplus of power. Even the cane trucks and agricultural machinery burn a blend of diesel and ethanol, while the favorite crop duster, a hot little plane called the **Ipanema,** is the first fixed-wing aircraft built to burn pure alcohol. "We're obsessed with efficiency," says plant director Agenor Cunha Pavan.

While corn ethanol's energy ratio hovers around breakeven, "we get eight units of ethanol for every one unit of fossil fuel," says Isaias Macedo, one of Brazil's leading sugarcane researchers. Experts estimate that producing and burning cane ethanol generates anywhere from 55 to 90 percent less carbon dioxide than gasoline. And Macedo envisions even greater efficiencies. "We can do the same thing with two-thirds or half of the bagasse, better manage tractors in the field, and approach levels of 12 or 13."

Even sugarcane isn't without its problems. While nearly all of São Martinho's cane is machine harvested, most Brazilian cane is cut by hand; the work, though well paid, is hot, dirty, and backbreaking. Cutters die of exhaustion every year, say leaders of their union. And to kill snakes and make the cane easier to cut by hand, the fields are usually burned before harvest, filling the air with soot while releasing methane and nitrous oxide, two potent greenhouse gases.

The expansion of Brazil's cane acreage—set to nearly double over the next decade—may also be contributing to deforestation. By displacing ranching in existing agricultural areas, sugar may be adding to the pressures that send cattlemen deeper into frontier territory like the Amazon and the biologically diverse savannas known as the **cerrado.** "If alcohol is now considered a 'clean' fuel, the process of making it is very dirty," says Marcelo Pedroso Goulart, a prosecutor for the Public Ministry of São Paulo. "Especially the burning of cane and the exploitation of the cane workers." Every biofuel also consumes crops that could be feeding a hungry globe. A recent UN report concludes that although the potential benefits are large, the biofuels boom could reduce food security and drive up food prices in a world where 25,000 people die of hunger every day, most under age five. Demand for both fuel and food is expected to more than double by mid-century, and many scientists fear that in coming decades, climate change will undermine agricultural productivity. "Agriculture should be used to stop the hunger of the people. If one person were hungry, this would be a shame," says Goulart. "There are millions who are hungry in Brazil, and this monoculture does not help."

The only way to reap the benefits of biofuels without squeezing the food supply is to take food out of the picture. Though corn kernels and cane juice are the traditional sources of ethanol, you can also make it from stalks, leaves, and even sawdust—plant by-products that are normally dumped, burned, or plowed back under. These materials are mostly cellulose, the tough chains of sugar molecules that make up plant cell walls. Breaking up those chains and fermenting the sugars could yield a cornucopia of biofuels, without competing with food crops. Biofuel visionaries picture a resurgence of deep-rooted perennial prairie grasses like switchgrass or buffalo grass, sequestering carbon in the soil, providing wildlife habitat and erosion control, and supplying a bounty of homegrown fuel.

The principle behind cellulosic ethanol is simple. Making it as cheap as gas isn't.

So far, only a few pilot plants are making ethanol from cellulose in the U.S. A small operation at the National Renewable Energy Lab (NREL) in Golden, Colorado, has been running the longest. It can convert a ton of biomass—shredded cornstalks, switchgrass, wood—into 70 gallons (265 liters) of ethanol in about a week. Along with cellulose and hemicellulose, these feedstocks all contain a substance called lignin. Lignin binds the cellulose molecules together, giving plants the structural strength to stand up and catch the sun. The gluey lignin also makes plant matter hard to break down, as the pulp and paper industry is well aware. "The old joke is you can make anything from lignin but money," says Andy Aden, a senior researcher on the ethanol project.

To unlock the cellulose molecules from the lignin, the feedstock is often pretreated with heat and acid. Then it's mixed with high-tech enzymes to break down the cellulose into sugars. The resulting dark brown goo, with a slightly sweet, molasses-like aroma, is fed into fermentation tanks where bacteria or yeast go to work to make the alcohol. The current process turns just 45 percent of the energy content in the biomass into alcohol, compared with an oil refinery, which extracts 85 percent of the energy in crude oil. The efficiency will have to improve for cellulosic ethanol to compete with gasoline, and researchers are looking for better cellulose-busters. One possibility: genetically modified microbes and enzymes from the guts of termites—

nature's own cellulosic energy factories.

The potential, however, is huge. Exploiting the cellulose in corn plants, rather than just the kernels, could double corn's ethanol yield; switchgrass could produce as much ethanol per acre as sugarcane. A 2005 study by the U.S. Department of Agriculture and the U.S. Department of Energy estimated that by boosting farm productivity and planting 50 million acres (20 million hectares) of fallow land with perennial grasses and fast-growing trees, the U.S. could produce 1.3 billion tons (about 1.2 billion metric tons) of feedstock for ethanol. Separately, NREL calculated that all that plant matter could replace more than half the transportation fuel currently burned each year. Mike Pacheco, former director of NREL's Bio-energy Center, pulls out a chart from that study. "The green line is what we think we can make on farms and from trees and switchgrass"—the equivalent of 3.5 billion barrels of oil.

Pacheco traces another line on his chart, at twice the altitude of the first. It represents the ultimate biofuels dream: enough green fuel to make the U.S. energy independent. It is where we might be, says Pacheco, if we greatly increase vehicle efficiency while churning out cellulosic ethanol, or, more tantalizing, "if we make algae work." There is no magic-bullet fuel crop that can solve our energy woes without harming the environment, says virtually every scientist studying the issue. But most say that algae—single-celled pond scum—comes closer than any other plant because it grows in wastewater, even seawater, requiring little more than sunlight and carbon dioxide to flourish. NREL had an algae program for 17 years until it was shut down in the mid-1990s for lack of funding. This year the lab is cranking it back up again. A dozen start-up companies are also trying to convert the slimy green stuff into a viable fuel.

GreenFuel Technologies, of Cambridge, Massachusetts, is at the head of the pack. Founded by MIT chemist Isaac Berzin, the company has developed a process that uses algae in plastic bags to siphon carbon dioxide from the smoke-stack emissions of power plants. Algae not only reduce a plant's global warming gases, but also devour other pollutants. Some algae make starch, which can be processed into ethanol; others produce tiny droplets of oil that can be brewed into biodiesel or even jet fuel. Best of all, algae in the right conditions can double in mass within hours. While each acre of corn produces around 300 gallons (1,135 liters) of ethanol a year and an acre of soybeans around 60 gallons (227 liters) of biodiesel, each acre of algae theoretically can churn out more than 5,000 gallons (19,000 liters) of biofuel each year.

"Corn or soybeans, you harvest once a year," says Berzin. "Algae you harvest every day. And we've proved we can grow algae from Boston to Arizona." Berzin's company has partnered with Arizona Public Service, the state's largest utility, to test algae production at APS's natural-gas-burning Redhawk power plant just west of Phoenix. Algae farms around that one plant, located on 2,000 acres (809 hectares) of bone-dry Sonoran Desert, could double the current U.S. production of biodiesel, says Berzin.

The energy farm, as GreenFuel calls it, isn't much to look at, just a cluster of shipping containers and office trailers next to a plastic greenhouse structure longer than a football field and perhaps 50 feet (15 meters) wide. Outside the greenhouse, rows of large plastic tubes filled with bubbling bright green liquid hang like giant slugs from hooks. After making a few calls to his boss, GreenFuel's security-conscious head of field operations, Marcus Gay, allows me to inspect this "seed farm," which grows algae for the greenhouse. Everything else is off-limits. The company guards its secrets closely.

With good reason: Only perhaps a dozen people on the planet know how to grow algae in high-density systems, says Gay. Algae specialists, long near the bottom of the biology food chain, are becoming the rock stars. Two of Arizona's largest universities recently started algae programs. Their biggest challenge, as with cellulosic ethanol, is reducing the cost of algae fuel. "At the end of the day for this to work, this has to be cheaper than petroleum diesel," says Gay. "If we're one penny over the cost of diesel per gallon, we're sunk." (In July, rising costs and technical problems forced GreenFuel to shut down the Redhawk bioreactor temporarily.)

Hard numbers—supply, efficiency, and, most important, price at the pump—will determine the future of ethanol and biodiesel. But for now green fuels have an undeniable romance. In the garage of his office complex in downtown Phoenix, Ray Hobbs, a senior engineer for APS who is leading the company's fuel initiative, walks past a small fleet of electric cars, hybrids, even a hydrogen-powered bus. He climbs into a big diesel Ford van and turns the key. The exhaust, unlike a typical diesel's, is invisible, with just the faintest whiff of diesel smell from the algae biodiesel made at the Redhawk pilot plant. The superslick plant oil has also quieted a little of that annoying diesel rattle.

"The way I think about these things is I'm sitting in a river in a canoe," says Hobbs. "Now do I want to paddle upstream, or do I want to go with the flow? Algae is downstream, with the flow. We have processes in nature that are honed for us, that have evolved. So we can take those processes and make them faster and more efficient and harness that power. We can't wait generations to screw around with this. We have to do it now."

Hobbs says he has fielded dozens of calls from power companies interested in building an algae plant of their own to scrub emissions and help meet their renewable fuels mandate. The lure of plant fuels even seems to have reached the petroleum-rich sands of the Middle East, where the United Arab Emirates has launched a 250-million-dollar renewable energy initiative that includes biofuels—perhaps a sign that even the sheikhs now realize that the oil age won't last forever. As precedents for such collective effort, people sometimes point to the Manhattan Project to build a nuclear weapon or the Apollo Program to put a man on the moon. But those analogies don't really work. They demanded the intense concentration of money and intelligence on a single small niche in our technosphere. Now we need almost the opposite: a commitment to take what we already know how to do and somehow spread it into every corner of our economies, and indeed our most basic activities. It's as if NASA's goal had been to put all of us on the moon.

Not all the answers are technological, of course—maybe not even most of them. Many of the paths to stabilization run straight through our daily lives, and in every case they will demand difficult changes. Air travel is one of the fastest growing sources of carbon emissions around the world, for instance, but even many of us who are noble about changing lightbulbs and happy to drive hybrid cars chafe at the thought of not jetting around the country or the world. By now we're used to ordering take-out food from every corner of the world every night of our lives— according to one study, the average bite of food has traveled nearly 1,500 miles before it reaches an American's lips, which means it's been marinated in (crude) oil. We drive alone, because it's more convenient than adjusting our schedules for public transit. We build ever bigger homes even as our family sizes shrink, and we watch ever bigger TVs, and—well, enough said. We need to figure out how to change those habits.

Probably the only way that will happen is if fossil fuel costs us considerably more. All the schemes to cut carbon emissions—the so-called cap-and-trade systems, for instance, that would let businesses bid for permission to emit—are ways to make coal and gas and oil progres- sively more expensive, and thus to change the direction in which economic gravity pulls when it applies to energy. If what we paid for a gallon of gas reflected even a portion of its huge environmental cost, we'd be driving small cars to the train station, just like the Europeans. And we'd be riding bikes when the sun shone.

The most straightforward way to raise the price would be a tax on carbon. But that's not easy. Since everyone needs to use fuel, it would be regressive—you'd have to figure out how to keep from hurting poor people unduly. And we'd need to be grown-up enough to have a real conversation about taxes—say, about switching away from taxes on things we like (employment) to taxes on things we hate (global warming). That may be too much to ask for—but if it is, then what chance is there we'll be able to take on the even more difficult task of persuading the Chinese, the Indians, and all who are lined up behind them to forgo a coal-powered future in favor of something more manageable? We know it's possible—earlier this year a UN panel estimated that the total cost for the energy transition, once all the pluses and minuses were netted out, would be just over 0.1 percent of the world's economy each year for the next quarter century. A small price to pay.

In the end, global warming presents the greatest test we humans have yet faced. Are we ready to change, in dramatic and prolonged ways, in order to offer a workable future to subsequent generations and diverse forms of life? If we are, new technologies and new habits offer some promise. But only if we move quickly and decisively—and with a maturity we've rarely shown as a society or a species. It's our coming-of-age moment, and there are no certainties or guarantees. Only a window of possibility, closing fast but still ajar enough to let in some hope.

Thursday, Mar. 27, 2008

The Clean Energy Scam

By Michael Grunwald

From his Cessna a mile above the southern Amazon, John Carter looks down on the destruction of the world's greatest ecological jewel. He watches men converting rain forest into cattle pastures and soybean fields with bulldozers and chains. He sees fires wiping out such gigantic swaths of jungle that scientists now debate the "savannization" of the Amazon. Brazil just announced that deforestation is on track to double this year; Carter, a Texas cowboy with all the subtlety of a chainsaw, says it's going to get worse fast. "It gives me goose bumps," says Carter, who founded a nonprofit to promote sustainable ranching on the Amazon frontier. "It's like witnessing a rape."

The Amazon was the chic eco-cause of the 1990s, revered as an incomparable storehouse of biodiversity. It's been overshadowed lately by global warming, but the Amazon rain forest happens also to be an incomparable storehouse of carbon, the very carbon that heats up the planet when it's released into the atmosphere. Brazil now ranks fourth in the world in carbon emissions, and most of its emissions come from deforestation. Carter is not a man who gets easily spooked--he led a reconnaissance unit in Desert Storm, and I watched him grab a small anaconda with his bare hands in Brazil--but he can sound downright panicky about the future of the forest. "You can't protect it. There's too much money to be made tearing it down," he says. "Out here on the frontier, you really see the market at work."

This land rush is being accelerated by an unlikely source: biofuels. An explosion in demand for farm-grown fuels has raised global crop prices to record highs, which is spurring a dramatic expansion of Brazilian agriculture, which is invading the Amazon at an increasingly alarming rate.

Propelled by mounting anxieties over soaring oil costs and climate change, biofuels have become the vanguard of the green-tech revolution, the trendy way for politicians and corporations to show they're serious about finding alternative sources of energy and in the process slowing global warming. The U.S. quintupled its production of ethanol--ethyl alcohol, a fuel distilled from plant matter--in the past decade, and Washington has just mandated another fivefold increase in renewable fuels over the next decade. Europe has similarly aggressive biofuel mandates and subsidies, and Brazil's filling stations no longer even offer plain gasoline. Worldwide investment in biofuels rose from $5 billion in 1995 to $38 billion in 2005 and is expected to top $100 billion by 2010, thanks to investors like Richard Branson and George Soros, GE and BP, Ford and Shell, Cargill and the Carlyle Group. Renewable fuels has become one of those motherhood-and-apple-pie catchphrases, as unobjectionable as the troops or the middle class.

But several new studies show the biofuel boom is doing exactly the opposite of what its proponents intended: it's dramatically accelerating global warming, imperiling the planet in the name of saving it. Corn ethanol, always environmentally suspect, turns out to be environmentally disastrous. Even cellulosic ethanol made from switchgrass, which has been promoted by eco-activists and eco-investors as well as by President Bush as the fuel of the future, looks less green than oil-derived gasoline.

Meanwhile, by diverting grain and oilseed crops from dinner plates to fuel tanks, biofuels are jacking up world food prices and endangering the hungry. The grain it takes to fill an SUV tank with ethanol could feed a person for a year. Harvests are being plucked to fuel our cars instead of ourselves. The U.N.'s World Food Program says it needs $500 million in additional funding and supplies, calling the rising costs for food nothing less than a global emergency. Soaring corn prices have sparked tortilla riots in Mexico City, and skyrocketing flour prices have destabilized Pakistan, which wasn't exactly tranquil when flour was affordable.

Biofuels do slightly reduce dependence on imported oil, and the ethanol boom has created rural jobs while enriching some farmers and agribusinesses. But the basic problem with most biofuels is amazingly simple, given that researchers have ignored it until now: using land to grow fuel leads to the destruction of forests, wetlands and grasslands that store enormous amounts of carbon.

Backed by billions in investment capital, this alarming phenomenon is replicating itself around the world. Indonesia has bulldozed and burned so much wilderness to grow palm oil trees for biodiesel that its ranking among the world's top carbon emitters has surged from 21st to third according to a report by Wetlands International. Malaysia is converting forests into palm oil farms so rapidly that it's running out of uncultivated land. But most of the damage created by biofuels will be less direct and less obvious. In Brazil, for instance, only a tiny portion of the Amazon is being torn down to grow the sugarcane that fuels most Brazilian cars. More deforestation results from a chain reaction so vast it's subtle: U.S. farmers are selling one-fifth of their corn to ethanol production, so U.S. soybean farmers are switching to corn, so Brazilian soybean farmers are expanding into cattle pastures, so Brazilian cattlemen are displaced to the Amazon. It's the remorseless economics of commodities markets. "The price of soybeans goes up," laments Sandro Menezes, a biologist with Conservation International in Brazil, "and the forest comes down."

Deforestation accounts for 20% of all current carbon emissions. So unless the world can eliminate emissions from all other sources--cars, power plants, factories, even flatulent cows--it needs to reduce deforestation or risk an environmental catastrophe. That means limiting the expansion of agriculture, a daunting task as the world's population keeps expanding. And saving forests is probably an impossibility so long as vast expanses of cropland are used to grow modest amounts of fuel. The biofuels boom, in short, is one that could haunt the planet for generations--and it's only getting started.

Why the Amazon Is on Fire

This destructive biofuel dynamic is on vivid display in Brazil, where a Rhode Island--size chunk of the Amazon was deforested in the second half of 2007 and even more was degraded by fire. Some scientists believe fires are now altering the local microclimate and could eventually reduce the Amazon to a savanna or even a desert. "It's approaching a tipping point," says ecologist Daniel Nepstad of the Woods Hole Research Center.

I spent a day in the Amazon with the Kamayura tribe, which has been forced by drought to replant its crops five times this year. The tribesmen I met all complained about hacking coughs and stinging eyes from the constant fires and the disappearance of the native plants they use for food, medicine and rituals. The Kamayura had virtually no contact with whites until the 1960s; now their forest is collapsing around them. Their chief, Kotok, a middle-aged man with an easy smile and Three Stooges hairdo that belie his fierce authority, believes that's no coincidence. "We are people of the forest, and the whites are destroying our home," says Kotok, who wore a ceremonial beaded belt, a digital watch, a pair of flip-flops and nothing else. "It's all because of money."

Kotok knows nothing about biofuels. He's more concerned about his tribe's recent tendency to waste its precious diesel-powered generator watching late-night soap operas. But he's right. Deforestation can be a complex process; for example, land reforms enacted by Brazilian President Luiz Inácio Lula da Silva have attracted slash-and-burn squatters to the forest, and "use it or lose it" incentives have spurred some landowners to deforest to avoid redistribution.

The basic problem is that the Amazon is worth more deforested than it is intact. Carter, who fell in love with the region after marrying a Brazilian and taking over her father's ranch, says the rate of deforestation closely tracks commodity prices on the Chicago Board of Trade. "It's just exponential right now because the economics are so good," he says. "Everything tillable or grazeable is gouged out and cleared."

That the destruction is taking place in Brazil is sadly ironic, given that the nation is also an exemplar of the allure of biofuels. Sugar growers here have a greener story to tell than do any other biofuel producers. They provide 45% of Brazil's fuel (all cars in the country are able to run on ethanol) on only 1% of its arable land. They've reduced fertilizer use while increasing yields, and they convert leftover biomass into electricity. Marcos Jank, the head of their trade group, urges me not to lump biofuels together: "Grain is good for bread, not for cars. But sugar is different." Jank expects production to double by 2015 with little effect on the Amazon. "You'll see the expansion on cattle pastures and the Cerrado," he says.

So far, he's right. There isn't much sugar in the Amazon. But my next stop was the Cerrado, south of the Amazon, an ecological jewel in its own right. The Amazon gets the ink, but the Cerrado is the world's most biodiverse savanna, with 10,000 species of plants, nearly half of which are found nowhere else on earth, and more mammals than the African bush. In the natural Cerrado, I saw toucans and macaws, puma tracks and a carnivorous flower that lures flies by smelling like manure. The Cerrado's trees aren't as tall or dense as the Amazon's, so they don't store as much carbon, but the region is three times the size of Texas, so it stores its share.

At least it did, before it was transformed by the march of progress--first into pastures, then into sugarcane and soybean fields. In one field I saw an array of ovens cooking trees into charcoal, spewing Cerrado's carbon into the atmosphere; those ovens used to be ubiquitous, but most of the trees are gone. I had to travel hours through converted Cerrado to see a 96-acre (39 hectare) sliver of intact Cerrado, where a former shopkeeper named Lauro Barbosa had spent his life savings for a nature preserve. "The land prices are going up, up, up," Barbosa told me. "My friends say I'm a fool, and my wife almost divorced me. But I wanted to save something before it's all gone."

The environmental cost of this cropland creep is now becoming apparent. One groundbreaking new study in Science concluded that when this deforestation effect is taken into account, corn ethanol and soy biodiesel produce about twice the emissions of gasoline. Sugarcane ethanol is much cleaner, and biofuels created from waste products that don't gobble up land have real potential, but even cellulosic ethanol increases overall emissions when its plant source is grown on good cropland. "People don't want to believe renewable fuels could be bad," says the lead author, Tim Searchinger, a Princeton scholar and former Environmental Defense attorney. "But when you realize we're tearing down rain forests that store loads of carbon to grow crops that store much less carbon, it becomes obvious."

The growing backlash against biofuels is a product of the law of unintended consequences. It may seem obvious now that when biofuels increase demand for crops, prices will rise and farms will expand into nature. But biofuel technology began on a small scale, and grain surpluses were common. Any ripples were inconsequential. When the scale becomes global, the outcome is entirely different, which is causing cheerleaders for biofuels to recalibrate. "We're all looking at the numbers in an entirely new way," says the Natural Resources Defense Council's Nathanael Greene, whose optimistic "Growing Energy" report in 2004 helped galvanize support for biofuels among green groups.

Several of the most widely cited experts on the environmental benefits of biofuels are warning about the environmental costs now that they've recognized the deforestation effect. "The situation is a lot more challenging than a lot of us thought," says University of California, Berkeley, professor Alexander Farrell, whose 2006 Science article calculating the emissions reductions of various ethanols used to be considered the definitive analysis. The experts haven't given up on biofuels; they're calling for better biofuels that won't trigger massive carbon releases by displacing wildland. Robert Watson, the top scientist at the U.K.'s Department for the Environment, recently warned that mandating more biofuel usage--as the European Union is proposing--would be "insane" if it increases greenhouse gases. But the forces that biofuels have unleashed--political, economic, social--may now be too powerful to constrain.

America the Bio-Foolish

The best place to see this is America's biofuel mecca: Iowa. Last year fewer than 2% of U.S. gas stations offered ethanol, and the country produced 7 billion gal. (26.5 billion L) of biofuel, which cost taxpayers at least $8 billion in subsidies. But on Nov. 6, at a biodiesel plant in Newton, Iowa, Hillary Rodham Clinton unveiled an eye-popping plan that would require all stations to offer ethanol by 2017 while mandating 60 billion gal. (227 billion L) by 2030. "This is the fuel for a much brighter future!" she declared. Barack Obama immediately criticized her--not for proposing such an expansive plan but for failing to support ethanol before she started trolling for votes in Iowa's caucuses.

If biofuels are the new dotcoms, Iowa is Silicon Valley, with 53,000 jobs and $1.8 billion in income dependent on the industry. The state has so many ethanol distilleries under construction that it's poised to become a net importer of corn. That's why biofuel-pandering has become virtually mandatory for presidential contenders. John McCain was the rare candidate who vehemently opposed ethanol as an outrageous agribusiness boondoggle, which is why he skipped Iowa in 2000. But McCain learned his lesson in time for this year's caucuses. By 2006 he was calling ethanol a "vital alternative energy source."

Members of Congress love biofuels too, not only because so many dream about future Iowa caucuses but also because so few want to offend the farm lobby, the most powerful force behind biofuels on Capitol Hill. Ethanol isn't about just Iowa or even the Midwest anymore. Plants are under construction in New York, Georgia, Oregon and Texas, and the ethanol boom's effect on prices has helped lift farm incomes to record levels nationwide.

Someone is paying to support these environmentally questionable industries: you. In December, President Bush signed a bipartisan energy bill that will dramatically increase support to the industry while mandating 36 billion gal. (136 billion L) of biofuel by 2022. This will provide a huge boost to grain markets.

Why is so much money still being poured into such a misguided enterprise? Like the scientists and environmentalists, many politicians genuinely believe biofuels can help decrease global warming. It makes intuitive sense: cars emit carbon no matter what fuel they burn, but the process of growing plants for fuel sucks some of that carbon out of the atmosphere. For years, the big question was whether those reductions from carbon sequestration outweighed the "life cycle" of carbon emissions from farming, converting the crops to fuel and transporting the fuel to market. Researchers eventually concluded that yes, biofuels were greener than gasoline. The improvements were only about 20% for corn ethanol because tractors, petroleum-based fertilizers and distilleries emitted lots of carbon. But the gains approached 90% for more efficient fuels, and advocates were confident that technology would progressively increase benefits.

There was just one flaw in the calculation: the studies all credited fuel crops for sequestering carbon, but no one checked whether the crops would ultimately replace vegetation and soils that sucked up even more carbon. It was as if the science world assumed biofuels would be grown in parking lots. The deforestation of Indonesia has shown that's not the case. It turns out that the carbon lost when wilderness is razed overwhelms the gains from cleaner-burning fuels. A study by University of Minnesota ecologist David Tilman concluded that it will take more than 400 years of biodiesel use to "pay back" the carbon emitted by directly clearing peat lands to grow palm oil; clearing grasslands to grow corn for ethanol has a payback period of 93 years. The result is that biofuels increase demand for crops, which boosts prices, which drives agricultural expansion, which eats forests. Searchinger's study concluded that overall, corn ethanol has a payback period of about 167 years because of the deforestation it triggers.

Not every kernel of corn diverted to fuel will be replaced. Diversions raise food prices, so the poor will eat less. That's the reason a U.N. food expert recently called agrofuels a "crime against humanity." Lester Brown of the Earth Policy Institute says that biofuels pit the 800 million people with cars against the 800 million people with hunger problems. Four years ago, two University of Minnesota researchers predicted the ranks of the hungry would drop to 625 million by 2025; last year, after adjusting for the inflationary effects of biofuels, they increased their prediction to 1.2 billion.

Industry advocates say that as farms increase crop yields, as has happened throughout history, they won't need as much land. They'll use less energy, and they'll use farm waste to generate electricity. To which Searchinger says: Wonderful! But growing fuel is still an inefficient use of good cropland. Strange as it sounds, we're better off growing food and drilling for oil. Sure, we should conserve fuel and buy efficient cars, but we should keep filling them with gas if the alternatives are dirtier.

The lesson behind the math is that on a warming planet, land is an incredibly precious commodity, and every acre used to generate fuel is an acre that can't be used to generate the food needed to feed us or the carbon storage needed to save us. Searchinger acknowledges that biofuels can be a godsend if they don't use arable land. Possible feedstocks include municipal trash, agricultural waste, algae and even carbon dioxide, although none of the technologies are yet economical on a large scale. Tilman even holds out hope for fuel crops--he's been experimenting with Midwestern prairie grasses--as long as they're grown on "degraded lands" that can no longer support food crops or cattle.

Changing the Incentives

That's certainly not what's going on in Brazil. There's a frontier feel to the southern Amazon right now. Gunmen go by names like Lizard and Messiah, and Carter tells harrowing stories about decapitations and castrations and hostages. Brazil has remarkably strict environmental laws--in the Amazon, landholders are permitted to deforest only 20% of their property--but there's not much law enforcement. I left Kotok to see Blairo Maggi, who is not only the soybean king of the world, with nearly half a million acres (200,000 hectares) in the province of Mato Grosso, but also the region's governor. "It's like your Wild West right now," Maggi says. "There's no money for enforcement, so people do what they want."

Maggi has been a leading pioneer on the Brazilian frontier, and it irks him that critics in the U.S.--which cleared its forests and settled its frontier 125 years ago but still provides generous subsidies to its farmers--attack him for doing the same thing except without subsidies and with severe restrictions on deforestation. Imagine Iowa farmers agreeing to keep 80%--or even 20%--of their land in native prairie grass. "You make us sound like bandits," Maggi tells me. "But we want to achieve what you achieved in America. We have the same dreams for our families. Are you afraid of the competition?"

Maggi got in trouble recently for saying he'd rather feed a child than save a tree, but he's come to recognize the importance of the forest. "Now I want to feed a child and save a tree," he says with a grin. But can he do all that and grow fuel for the world as well? "Ah, now you've hit the nail on the head." Maggi says the biofuel boom is making him richer, but it's also making it harder to feed children and save trees. "There are many mouths to feed, and nobody's invented a chip to create protein without growing crops," says his pal Homero Pereira, a congressman who is also the head of Mato Grosso's farm bureau. "If you don't want us to tear down the forest, you better pay us to leave it up!"

Everyone I interviewed in Brazil agreed: the market drives behavior, so without incentives to prevent deforestation, the Amazon is doomed. It's unfair to ask developing countries not to develop natural areas without compensation. Anyway, laws aren't enough. Carter tried confronting ranchers who didn't obey deforestation laws and nearly got killed; now his nonprofit is developing certification programs to reward eco-sensitive ranchers. "People see the forest as junk," he says. "If you want to save it, you better open your pocketbook. Plus, you might not get shot."

The trouble is that even if there were enough financial incentives to keep the Amazon intact, high commodity prices would encourage deforestation elsewhere. And government mandates to increase biofuel production are going to boost commodity prices, which will only attract more investment. Until someone invents that protein chip, it's going to mean the worst of everything: higher food prices, more deforestation and more emissions.

Advocates are always careful to point out that biofuels are only part of the solution to global warming, that the world also needs more energy-efficient lightbulbs and homes and factories and lifestyles. And the world does need all those things. But the world is still going to be fighting an uphill battle until it realizes that right now, biofuels aren't part of the solution at all. They're part of the problem.

Products that use Corn

Adhesives (glues, pastes, mucilages, gums, etc.)
Aluminum
Antibiotics (penicillin)
Asbestos insulation
Aspirin
Automobiles (everything on wheels)
- **cylinder heads**
- **ethanol - fuel & windshield washer fluid**
- **spark plugs**
- **synthetic rubber finishes**
- **tires**

Baby food
Batteries, dry cell
Beer
Breakfast cereals
Candies
Canned vegetables
Carbonated beverages
Cheese spreads
Chewing gum
Chocolate products
Coatings on wood, paper & metal
Colour carrier in paper & textile, printing
Corn chips
Corn meal
Cosmetics
C.M.A. (calcium magnesium acetate)
Crayon and chalk
Degradable plastics
Dessert powders
Dextrose (intravenous solutions, icing sugar)
Disposable diapers
Dyes
Edible oil
Ethyl and butyl alcohol
Explosives - firecrackers
Finished leather
Flour & grits
Frozen foods
Fructose
Fuel ethanol
Gypsum wallboard
Ink for stamping prices in stores
Insecticides
Instant coffee & tea
Insulation, fibreglass
James, jellies and preserves
Ketchup
Latex paint
Leather tanning
Licorice
Livestock feed
Malted products
Margarine
Mayonnaise
Mustard, prepared
Paper board, (corrugating, laminating, cardboard)
Paper manufacturing
Paper plates & Cups
Peanut butter
Pharmaceuticals - The Life Line of The Hospital
Potato chips
Rugs, carpets
Salad dressings
Shaving cream & lotions
Shoe polish
Soaps and cleaners
Soft drinks
Starch & glucose (over 40 types)
Syrup
Tacos, tortillas
Textiles
Toothpaste
Wallpaper
Wheat bread
Whiskey
Yogurts

Question: Of 10,000 items in a typical grocery store, how many would you guess would contain corn in one form or another?

Answer: At least 2,500 items use corn in some form during the production or processing.

How Corn is Used in Some of these Products

Beer	Beer manufacturing is a process of treating malt to convert and extract the barley starch to fermentable sugars using the amyloytic enzymes present in malt followed by yeast fermentation. However, demand for lighter, less filling beer, especially in the U.S., has permitted use of more refined carbohydrate sources of two types: a) dry adjuncts, primarily dry milled corn grits, broken rice, refined corn starch, and more recently, dextrose. b) liquid adjuncts, namely corn syrups
Cake Mixes	Cake mixes use a pregelatinized corn starch that will form a paste in cold or warm water. In baked goods that use yeast for rising, dextrose is used as a yeast nutrient.
Candies	Corn syrup is used in hard candies to provide a body giving them chewiness and a desirable mouthfeel without excessive sweetness. Candies that are coated use a pyrodextrin corn starch for the coating.
Carbonated Beverages - Coke	High fructose corn syrup (HFCS) blended with sucrose in a 50/50 blend is sweeter than the same concentration of sucrose. The use of HFCS in carbonated beverages is common throughout Canada and the U.S.
Cookies	Corn starch, corn flour or dextrose may be found in cookies.
Corn Flakes	The flaking grits are cooked to a rubbery consistency with syrup, malt, salt and flavouring added. After tempering, the cooked grits are flattened between large steel rolls, followed by toasting in travelling ovens to a golden brown colour.
Corn Starch	Corn starch is derived from the wet milling process and is an important manufactured product. Some uses depend on the properties in the dry state, but most applications relate to its properties as a cooked, hydrated paste.
Corn Meal	Corn meal is a popular dry corn product because of its long shelf life. It is used to produce an assortment of chemically leavened bread and fried products like corn bread and muffins.
Cosmetics	Corncobs, when finely ground, are relatively dust free and very absorbent. This absorbency makes corncobs useful carriers for pesticides, fertilizers, vitamins, hand soaps, cosmetics and animal litters.
Granola Dips/Granola Bars	Some types of Granola Dips use dextrose as a sweetener.
Gypsum Wallboard	Starch-containing corn flour is gelatinized during the manufacturing process; It functions by controlling the rate of water loss during drying of the board. Soluble carbohydrates migrate to the surface and control the rate of crystallization of the gypsum, providing a strong bond between the gypsum and the liner.
Instant Coffee & Tea	Maltodextrins are derived from the wet milling process. They are a dextrose equivalent product of complete solubility but little or no sweetness. Maltodextrins are sprayed on instant tea and coffee to keep the granules free flowing. This solution is also used in instant soup mixes or other packages where the contents must be be kept free flowing.
Mars Bar & Twix Bar	Many candy bars contain corn syrup.
Paint and Varnish	Tetrahydrofurfuryl alcohol is a resin developed from processing corncobs. These resins are useful in the paint and varnish industry as solvents for dyes, resins, and lacquers.
Paper Products	Paper products use raw starch in the manufacturing process. The properties of high paste viscosity and strong gels are useful in specially coated papers.

	Pyrodextrins are also used for paper manufacturing for the adhesive property on remoistenable gums for postage stamps and packaging tape.
Pharmaceuticals	Aspirin - an oxidized starch paste, which dries to a clear, adherent, continuous film, is spread in a thin layer over the aspirin.Intravenous - some IVs consist of dextrose and water solutions. Antibiotics - preferred carbohydrate sources are corn syrup, dextrose, corn starch, lactose and sucrose. Cornsteep liquor was early found to provide a ready source of soluble nitrogenous nutrients plus unknown growth factors that stimulate antibiotic production. Over 85 different types of antibiotics are produced using corn.
Snack Foods - Corn Chips & Doritos	These snack foods are generally made from whole corn (cornmeal). The high starch content of cornmeal and flour is important in giving a high puff in preparation of extruded (pressed) snack products in which a delicate corn flavour is desired.
Spark Plugs	Starch is used in the production of the porcelain part of spark plugs.
Tire, Rubber	In the production of tires, corn starch is sprinkled on the molds before pouring the rubber, to prevent the rubber from sticking to the molds.
Toothpaste	Sorbitol, which is produced from the corn sugar dextrose, is used in toothpaste as a low-calorie, water-soluble, bulking agent.
Whiskey	The major carbohydrate in the production of whiskey is corn.A typical Canadian whiskey is made from a mixture of about 90% corn, 5% rye, and 5% barley malt.
Yogurt	Some of the different brands of yogurt use corn syrup as a sweetener.