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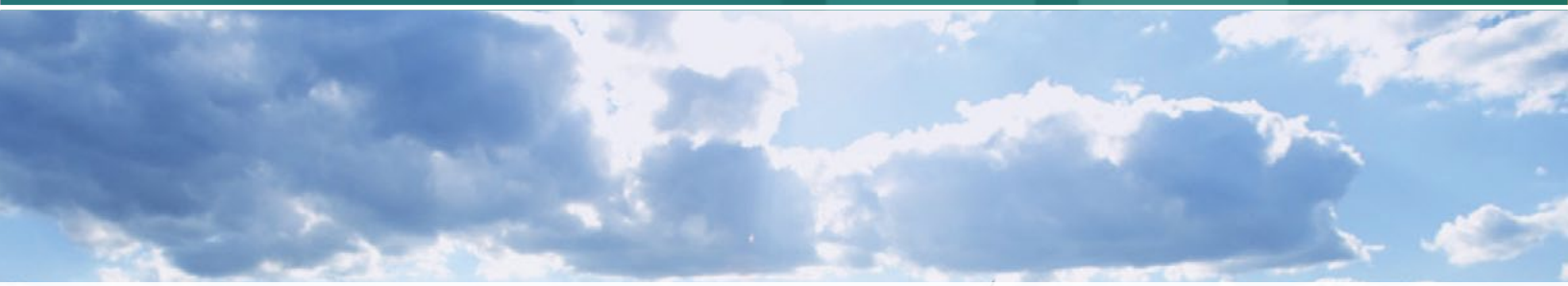


Innovation: Harnessing the Power of New Ideas

July 2013

A White Paper from BioResource International, Inc.

www.briworldwide.com

TABLE OF CONTENTS

INTRODUCTION

Innovation is an extremely hot topic these days, used to describe hundreds of companies from start-ups to multinational corporations. Go to any corporate website and chances are you'll see it mentioned at least once. Unfortunately, it's not so clear what exactly innovation is.

For one thing, the term has become a bit cliché. "Innovative" was the seventh most used buzzword in the LinkedIn profiles of U.S. professionals last year. *The Wall Street Journal* reports that companies across a wide range of industries used some variation of "innovation" 33,528 times in their annual and quarterly reports in 2011, and that more than 250 books with "innovation" in the title were published in the first quarter of 2012.

In addition, innovation means different things to different people. Definitions obtained by the WSJ from company executives range from "inventing a product that has never existed, such as packing material that inflates on delivery" (Bill Hickey, Sealed Air Corp.), to "turning an overlooked commodity, such as leftover cranberry skins, into a consumer snack" (Randy Papadellis, Ocean Spray Cranberries), to "extending a product's scope and application, such as expanding the use of a vaccine for infants that is also effective for older adults" (Mikael Dolsten, Pfizer).

Then again, Scott Berkun, author of *The Myths of Innovation*, tells us that a majority of companies claiming to innovate simply mean that they are coming up with "a very good product." This definition substantially dilutes innovation's impact.

In this white paper, we will present to you what we think innovation is (and isn't). We will also go over the characteristics that drive innovation in small companies and large sovereign countries. Finally, we will narrow our focus to innovations in the agriculture industry and how these innovations contribute to increased efficiencies in the production of food, fuel and fiber.

SO YOU HAVE A PATENT. YOU'RE NOT INNOVATIVE...YET

In the simplest sense, innovation means applying new thinking to solve existing problems. In the biotechnology industry, for instance, owning several patents does not, by itself, make a company innovative—not until it actualizes the potential of those patents in a way that addresses a need or problem.

Inventors come up with ideas and methods. Innovators take those ideas and methods and ground them in reality. They figure out how an invention can make an existing process better without disrupting it, or how it can solve problems without requiring users to exert too much effort.

In his book, *Go It Alone!*, Bruce Judson quoted Harvard Business School professor Rosabeth Moss Kanter, who said that "the path to success involves staying a little ahead of the competition but close enough that customers can understand your product and incorporate it into their lives and businesses," and that "years of research shows that innovations most likely to hold are those that don't demand excessive change from the customer."

Innovators understand that people don't like it when things change too much. They know that the market welcomes new and better products and processes all the time, but only if they fit into a paradigm that customers can appreciate and understand.

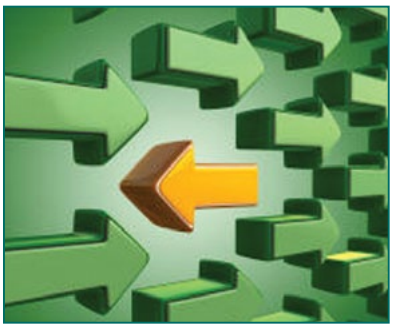
When BRI first licensed its enzyme technology from North Carolina State University, we were focused on making feather protein more digestible…a bit too revolutionary. It was quite a challenge to justify the cost of the enzyme treatment compared to the value of the enzyme-treated feather meal.

Innovation means applying new thinking to solve existing problems.

The innovative step? The realization that there was a larger, more lucrative market for an enzyme product that could increase the digestibility of protein in animal feed. Enzyme feed additives had been on the market for some time before we launched our product, so it was less of a leap for customers to appreciate and understand the value of our enzyme.

As you can see, it's a myth that all innovative companies must have disruptive technologies that can revolutionize an industry. Most innovative companies are successful because they engaged in a slow and steady process that progressively increased the value of their products and services to customers and stakeholders. Trying to come up with something totally new, while headline-grabbing, may actually be bad for business, because the copious amounts of time and resources needed to educate and convince potential customers may sink the company before significant market share is reached.

The bottom line is, innovation works best in an ecosystem. It doesn't exist by itself, but only within certain parameters.



THE PARADOX OF ENTREPRENEURIAL INNOVATION

It's easy to think that big, established companies are more likely to innovate than small ones. After all, they have more resources. They can hire new people and even create a department that focuses solely on applying new thinking to solve existing problems. A number of Fortune 500 companies now have chief innovation officers in their leadership teams.

In contrast, startups have too few people for too many jobs. Many are wearing multiple hats and working an ungodly number of hours. Who has the time to innovate when there are tests to run and money to raise? Also, startups are not yet financially viable, so it often doesn't make sense to throw cash at risky experiments.

But here lies the paradox of entrepreneurial innovation: the more constraints there are, the more innovation is likely to take place—or at least, the disruptive kind.

Sustaining versus Disruptive

In his book, *The Innovator's Dilemma*, Clayton M. Christensen distinguished disruptive innovation from sustaining innovation. Sustaining innovation improves past successes and provides the market with incremental value. An example of this would be a smaller, faster, and/or cheaper laptop computer. Large companies are well-positioned for this type of innovation because not only do they have more money and technological prowess, they also have an established reputation and a better understanding of customers. There's virtually no chance for a competitor that's starting from scratch to catch up.

Disruptive innovation, on the other hand, changes the game. It displaces industry leaders by rendering existing solutions obsolete. It's either so much cheaper that it opens up a new market or it grows within a niche that established companies ignore because it's too small. However, the disruptive technology performs so well that it catches up with—and eventually surpasses—the more mainstream technology. Think about MP3s and their devastating effect on records, tapes, and CDs.

Clyde Smith, who blogs about innovation in higher education, describes disruptive innovators as "stealth companies in plain view." Industry leaders see them but aren't threatened by them, only to realize their mistake later on. In his book, *The Master Switch*, Tim Wu tells the story of how Western Union, which dominated the telegraph industry in the late 19th century, settled out of court their challenge to AT&T's patent for telephony. (AT&T's predecessor is Alexander Graham Bell's The Bell Telephone Company, which CNN refers to as "*America's original startup*.")

In the settlement, the two companies agreed not to compete with each other. AT&T would leave the telegraph market, and Western Union would exit the telephone market. At the time, few people were using the telephone and long distance communication was only possible through telegraph—a technology that Western Union considered infinitely more valuable. But as we all know, the telephone eventually rendered the telegraph obsolete, and Western Union stopped providing the service in 2006.

Different Mindset

Why does this happen? What is it about the culture of small companies that makes it more conducive to out-of-the-box thinking? Wu explains: "The men dreaming of a better telegraph were, one might say, mentally warped by the tangible demand for a better telegraph. The demand for a telephone, meanwhile, was purely notional. Nothing, save the hangman's noose, concentrates the mind like piles of cash, and the obvious rewards awaiting any telegraph improver were a distraction for anyone even inclined to think about telephony, a fact that actually helped Bell."

In addition, the larger a company is, the more it has to lose. Thus, it takes longer to make decisions, tolerates less risk, has less flexibility, and needs more quantitative data to support new ventures. The consequences of success or failure are also different. For big companies, it's a bonus or a promotion (or the lack of it). For a startup, it's life or death of the company. So while employees working at a large company might have a professional interest in its success, those who working in startups tend to have a personal stake as well.

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So what's a mature company to do? How can it innovate without compromising the very traits that allow it to be so efficient and profitable? On the other hand, how can entrepreneurs and startups scale their innovations and build sustainable enterprises?

The trend in the pharmaceutical industry is for large companies to create venture capital firms that provide funding to promising startups. Then, once these startups reach certain product development milestones, the companies absorb them.

Companies in a variety of industries also form strategic partnerships. For instance, a mature company will partner with a startup that has specialized research and development capabilities, technology and patents, or a proprietary database of information. In BRI's case, we owned patented enzyme technologies that fit strategically with Novus International's existing CIBENZA feed additive portfolio. Novus is an animal health and nutrition company that operates in more than 90 countries.

In short, just because their culture is not very conducive to innovation doesn't mean that large companies should stop innovating in-house. But they shouldn't rely solely on that strategy either.

5 PRINCIPLES FOR BUILDING A CULTURE OF INNOVATION IN SMALL COMPANIES

Business writer and management guru Peter Drucker once remarked that "culture eats strategy for breakfast." As any successful entrepreneur who's been in business for a while can tell you, at some point you'll realize that you just can't control everything that happens to your company. But if you get the culture right, many things will go well without you even knowing about it.

Take, for instance, innovation. At BRI, we try to foster a culture of innovation. If, like us, you want to position your business for the future, here are our five principles for building a culture of innovation in your company.

1. Innovation is based on teamwork

Innovation is a multistep process that draws upon the talents of many. It's not just about people who can come up with new ideas (the inventors), but about people who excel at recognizing good ideas (Steve Jobs comes to mind). It's also about those who have a knack for selling ideas, as well those who are great at challenging, refining, and improving them. And finally, it's about people who can successfully implement ideas.

There is no way one person can be strong in all those areas. So before you can actualize an idea and use it to solve existing problems (the definition of innovation), make sure you're working as a team.

2. Innovation requires open communication

Efforts to innovate will fail unless everyone understands the "where" and "how." You need to communicate to your team where you want to go and how you plan to get there. While many aspects of a project may be highly technical, goals and processes shouldn't be.

Clearly defined goals and processes enable those involved to measure (and celebrate) their progress, understand the impact of their decisions, and resolve problems as early as possible. We would argue that open communication is one reason why start-ups often outpace larger, more well-funded companies when it comes to innovation.

3. Innovation is based on creating positive change

Moses Ma, who writes the column "The Tao of Innovation" in *Psychology Today*, says that innovation is a spiritual discipline that requires "exemplary positivity, perspective, and perseverance." It may take several years to a decade to commercialize an idea, and many things can and will go wrong along the way.

At BRI, we worked through various crises and challenges before finally turning the corner. Innovative small companies guard against discouragement by focusing on the future. We're constantly moving forward and changing things for the better, because we see how things could be, rather than how they are.

4. Innovation is based on fair competition

Innovation thrives in a properly regulated environment. However, in business, there will always be opportunities to take shortcuts or bend the rules to get ahead of the competition. My advice is—don't. There are legitimate ways to win in the marketplace, and while they usually require more work, winning fairly is the only sustainable way to succeed.

5. Innovation happens within an ecosystem

You may think that if you build a better mousetrap, the world (or at least those with a rodent problem) will beat a path to your door. However, successful innovators work within an ecosystem that considers factors such as cost and convenience.

Your product or service may be innovative, but if it costs significantly more than a competing offer, or if it requires several complicated steps or a paradigm shift in the industry to implement, then its chances of success will be low.

As a startup, building a culture of innovation might not be as high on your priority list as raising capital, hiring staff, and meeting product development milestones. But every company has a culture, and if you don't define and nurture it, your employees will define and develop one for themselves.

So if you want to build a culture of innovation, why not start now with a few of these principles in mind, and see if it works for you?

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5 CHARACTERISTICS OF INNOVATIVE COUNTRIES

Businesses aren't the only institutions that benefit from a culture of innovation. It's no accident that countries that embrace innovation are generally more prosperous and more attractive to outside investment. Innovation is clearly a competitive advantage—not just for companies, but also for countries.

So what makes some countries more innovative than others? In our view, there seems to be five characteristics that can be found in all countries that get innovation right (that is, they consistently apply new thinking to solve existing problems).

1. Strong scientific and technical infrastructure

Innovative nations have strong research university systems, without which it would be nearly impossible to attract the talent needed to drive innovation. High quality scientific and technical personnel gravitate toward places that have the resources they need to create new inventions and technologies.

But a strong research university system isn't enough. That system must also exist within a cluster of related and supporting organizations. New technologies, especially in the life sciences, often come out of universities (BRI's patented enzyme products, spun out of North Carolina State University, is one example), but this is only the first step.

To commercialize our technology, we had to work with firms that provide things such as incubator space, workforce development, and technology transfer services. All of these firms were conveniently located in Research Triangle Park, NC. Industry clusters also help to facilitate the flow of information, which leads to even more ideas and company spinoffs.

2. Diversity

Innovation often happens at the edge of cultures. When we see the word "diversity," we typically think of race, gender, and ethnicity. But it's really the cognitive differences that go hand-in-hand with our identity differences that create better business outcomes.

Diverse groups offer different ways of representing problems and situations, classifying and interpreting information, coming up with solutions, and predicting results. Their collective wisdom exceeds the sum of its parts. The U.S. is a prime example of this diversity, where people from a wide variety of cultures and backgrounds immigrate and integrate into the population as a whole, many through the university education system (see item #1).

In his book, *The Difference: How the Power of Diversity Creates Better Groups, Firms, Schools, and Societies*, Scott Page writes that while cognitive diversity doesn't do much for routine tasks (e.g., sealing envelopes, flipping burgers), it's a key performance variable in situations that require teamwork. And as mentioned earlier, teamwork is a core principle of innovation.

3. Young people

Unless there is a need in the market, even a country with all the raw materials to innovate won't have the incentive to do so. This demand side of innovation is typically associated with young people, because let's face it: young people are more likely to try new things and less likely to be encumbered with hard-wired habits and proclivities.

Young people also contribute to the supply side of innovation. They tend to take more risks and challenge the status quo—two traits necessary for innovation to happen. You'll notice that more and more people in their 20s are launching and growing *startups*, especially in the information technology and software industries.

4. Intellectual property protection

Some might argue that regulations can stymie innovation by requiring businesses to jump through hoops. But in some ways, they also facilitate it.

To tell the truth, most of us want to make the world a better place, but we're in business to make a profit. No for-profit company will devote massive amounts of resources to research and development if anyone can simply copy its products, not to mention sell them for a fraction of the price.

Innovative countries respect intellectual property rights. They offer patent protection and honor contracts (e.g., license agreements, buy-and-sell agreements) that make it possible for innovative individuals and businesses to earn reasonable returns on their investments.

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5. Risk-taking culture

While several countries in Asia have already surpassed the U.S. with regard to producing the so-called "raw materials" of innovation (e.g., high educational achievement of citizens, number of people graduating to become engineers and scientists, speed and penetration of broadband Internet service), they're still not as innovative, noted innovation consultant John Kao in his interview with *The New York Times*. What they lack, Kao said, "is a social environment that encourages diversity, experimentation, risk-taking, and combining skills from many fields into… 'recombinant mash-up' [products] like the iPhone, which redefined the smartphone category."

Meanwhile, in her article for the *Fung Global Institute*, Rachel Chan, co-founder of a Hong Kong-based organization that empowers young people in Asia to create positive personal, economic, social, and environmental change, noted that the lag in innovation has been attributed to Asian countries' "overemphasis on rote learning, obedience to authority, hierarchical relationships, and conformity."

Innovation takes place in a "climate where people feel free and safe to try out new ideas," said Chan. She then goes on to express hope that the situation in Asia will change, because many second or third generations of Asian business leaders— influenced by Western education and an organizational culture that encourages experimentation and risk-taking—are gradually taking over.

Obviously we at BRI have more of a U.S.-centric view and have benefited from many of the pro-innovation characteristics described above while starting and growing our business.

For example, we were founded by immigrants who studied in some of the best research universities in the country. Our headquarters are based in Research Triangle Park—a thriving biotechnology hub. We have a diverse team, most of whom are in their 20s, 30s, and 40s.

Last but not the least, our business is protected by patent and contract laws. This motivates us to continue investing in research and development for the betterment of the country that made it possible for BRI to take off and grow.

IMMIGRATION AND INNOVATION: WHAT'S THE CONNECTION?

Reform of the U.S. immigration system is a hot topic in Congress this year. While there are many sides and perspectives on the issues surrounding the Immigration Innovation Act of 2013, it's clear that U.S. innovation has benefited and continues to benefit from immigrants from all over the world. But what does immigration have to do with innovation? Quite a bit, it turns out.

Close to 40 percent of all Fortune 500 companies were founded by immigrants or children of immigrants, and 76 percent of patents issued to the country's top 10 university systems listed immigrant inventors, noted Flybridge Capital General Partner Jeffrey Bussgang, during his May 8 testimony on immigration reform before the U.S. Senate Committee on Commerce.

While founding Fortune 500 companies and filing patents do not make one innovative per se, the impressive achievements of U.S. immigrants reflect a culture that embraces diversity and opportunity, which in turn drives innovation. When you add to the mix diverse groups of highly skilled foreign workers in the science, technology, engineering, or mathematics (STEM) fields who come to the U.S. to train at the world's leading universities, you have a winning formula for fostering innovation across many sectors.

Immigration-driven innovation

The U.S. attracts a disproportionate number of highly qualified scientific and technical personnel from around the world largely because the resources these world-class researchers need can be found in many American universities.

Given access to these resources, foreigners are generally very productive. A paper published in the *Economic Journal* showed that increases in the number of foreign students lead to significantly more publications and citations from science and engineering departments in the U.S. Many foreigners want to stay in the U.S. after graduation to further their training and seek gainful employment. However, our immigration system ends up turning many of them away.

Right now, the only way for a foreign student who has graduated to stay in the U.S. for any significant period of time and start a business is to get a green card. This can only be done by marrying a U.S. citizen, obtaining a sponsorship from an American employer, or investing at least $500,000 in a commercial enterprise that would create or maintain 10 permanent full time jobs for American workers. As a result, many of the best and brightest are forced to abandon their dream of starting a business in the U.S. or to take that dream somewhere else.

Even for foreigners who just want to work for U.S. companies as employees, being able to stay in the country is far from guaranteed. For one thing, existing rules require newly graduated students to leave the country within 60 days unless they find a job with a company that will sponsor their H1-B (work) visa.

Even if the employer is willing to sponsor an employee, the H1-B has a restrictive cap that limits the number of visas issued each year. This year, the U.S. Citizenship and Immigration Services received more than enough petitions to fill the statutory limit of 65,000 H-1B petitions and 20,000 H1-B advanced degree exemptions on April 5th, just five days after it opened the application process.

Close to 40 percent of all Fortune 500 companies were founded by immigrants or children of immigrants, and three out of every four patents issued to the United States' top 10 university systems listed immigrant inventors.

Efficiency gains around the world

Cisco Chairman and CEO John Chambers, speaking on the topic of immigration and innovation, recently said that "America's success has been based upon its ability to attract the best, brightest, and most ambitious individuals. [It] needs a modern immigration policy that further fosters this culture to help spur continued technological innovation and economic growth."

We agree and anticipate that if passed, the Immigration Innovation Act of 2013 will be good not just the U.S. economy, but also for the economies of many other countries around the world. How is that possible? Because of limited access to strong scientific and technical infrastructure in their home countries, would-be inventors and innovators must emigrate to countries with strong university research systems, diverse populations, and risk-taking cultures to reach their full potential.

These inventors and innovators then contribute significantly to their home countries and newly adopted countries, whether through remittances; by applying their newly-honed skills to solve critical problems; or just like at BRI, creating more business opportunities for companies and more job opportunities for citizens.

THREE GREAT FARMING INNOVATIONS OF THE LAST CENTURY

We started this white paper by talking about innovation in the broadest sense of the word; what it is and what it isn't. We'll now narrow our focus on innovation to an area of particular interest for our readers: innovation in agriculture.

While agriculture is hardly a field that most people would associate with innovation, one could argue that farmers were and continue to be the first innovators—applying the latest tools, techniques, and knowledge available to confront the challenges of the day. Whether in pest resistance, better yields, higher grain prices, or hardiness to severe weather, innovation enables farmers all over the world to improve their lives and livelihoods.

We'll delve deeper into increased efficiencies in livestock production later.. For now, we'll address innovations in crop science—a timely topic given the intensifying need to feed the world and humankind's ongoing efforts to improve crop production. While there are innumerable advances that have taken place in farming over the years, here are our top three farming innovations of the last century.

1. Three-point hitch or linkage

Among countless developments in mechanized agriculture, the three-point hitch system, developed in the 1930s by Irish farmer Harry Ferguson and mass produced by Ford Motor Company, has perhaps made the biggest impact on farming efficiency. Before it was introduced, tractors were little more than mechanized horses, with plows, wheels, and other implements harnessed to them.

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By visualizing the tractor as a plowing tool and not a mechanized horse, Ferguson devised a system that made every implement, such as the ploughshare, part of the tractor. Using a lever that operated a hydraulic pump, farmers were able to raise or lower the plough depending on how deeply they wanted to dig into the ground. The forces the plough generated then transferred energy to the back wheels.

The system also prevented many farm accidents by overcoming the issue of instability. Previously, when implements were attached to tractors using chains, any number of obstructions on the ground would tip the tractor backwards, injuring the driver. Ferguson's design solved that problem.

With the addition of a few, mostly electronic, refinements, the three-point hitch is still the implement attachment and control system seen on almost all agricultural tractors today.

2. Semi-dwarf strains of wheat and the "Green Revolution"

Three major dwarfing genes were critical components of the "Green Revolution," —a series of agricultural innovations occurring between the 1940s and 1970s that dramatically increased grain production and saved more than a billion people worldwide from starvation.

In the early 1900s, Italian agronomist Nazareno Strampelli crossed the Japanese wheat variety Akakomugi—which contained the dwarfing Rht8 gene—with Dutch and Italian varieties in the hopes of increasing crop yield and making Italian wheat production self-sufficient. The resulting plants were shorter and thus less susceptible to wind damage and collapse. They also devoted less of their energy to growing taller and more to ripening grain.

Several decades later and across the ocean in Japan, U.S. Department of Agriculture biologist Cecil Salmon found Norin 10, a wheat variety with dwarfing genes Rht-B1b and Rht-D1b, while serving as advisor to the post-World War II occupation army. He sent Norin 10 to the U.S, where wheat breeder Orville Vogel crossed it with other varieties to create more short-straw wheats. Vogel shared his research with his colleague Norman Borlaug, who then used it and Strampelli's studies to develop techniques for cross-breeding, harvesting, and planting seeds to produce remarkably disease-resistant strains of wheat.

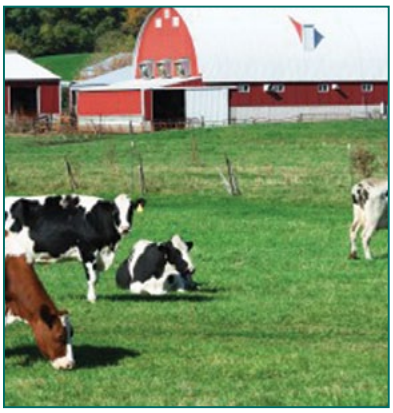
Known as the father of the Green Revolution, Borlaug introduced his new agricultural techniques to India, Pakistan, and other countries that were on the brink of famine or suffering from other food supply problems. Crop yields increased dramatically and per capita food supply was maintained throughout the late 20th century even as the world's population doubled.

3. Genetically-modified crops

Perspectives differ widely on the risks and benefits of crops that have been improved by advanced genetic techniques. However, from a scientific and productivity standpoint, the technology is sound. In fact, a majority of genetically modified (GM) crops, including corn and soybeans in North America, have been produced under strict governmental regulations and safely consumed for dozens of years without incident.

Scientists can genetically modify crops by isolating genes associated with desirable traits—such as drought tolerance, higher yield potential, and herbicide resistance—from some plant varieties and introducing those genes to other varieties. This enables farmers to grow crops with traits that would be difficult or impossible to achieve through conventional breeding.

Of course, GM crops alone can't solve the food crisis. No single innovation, no matter how helpful, can. Just consider how quickly a revolution that saved a billion lives has become inadequate in feeding our rapidly growing population. GM foods will almost certainly be part of the solution, but they're only one of several innovations that are taking place now to meet the challenge of feeding the world using less and less arable land.



THREE AREAS OF INNOVATION IN LIVESTOCK PRODUCTION

The United Nations Population Division estimates that by 2050, the number of people on Earth will be somewhere around 9.3 billion. We're headed toward a global food crisis unless agricultural output is able to keep up with our rapidly growing demand for food.

As mentioned earlier, a number of innovations are occurring in plant agriculture to maximize all of the land we can sustainably cultivate. From advanced plant breeding techniques, to integrated pest management, to genetically modified crop varieties, scientists and farmers are working together to increase the amount of crops produced per acre of land.

But stimulating higher crop yields is only one part of the solution to our food security problem. We also need to focus on increasing animal production. Livestock is one of the fastest growing agricultural sectors in developing countries, driven not just by population growth (most of the increase is projected to happen in developing countries), but by urbanization and higher incomes.

According to a 2012 McKinsey & Company report, "…the move to urban living is lifting the incomes of millions of people around the world. In cities, one billion people will enter the global 'consuming class' by 2025, with incomes high enough to become significant consumers of goods and services." Urbanization will likely come with infrastructure improvements that facilitate trade and this, combined with higher incomes, will drive up the demand for meat.

So just like in plant agriculture, innovations are taking place in animal nutrition, reproduction, and health—all of which are expected to increase animal agricultural output.

1. Animal nutrition

As a result of decades of research on various species and breeds of livestock all over the world, there's now a wealth of information on the nutritional needs of animals grown for food production. By applying this information, livestock producers can formulate feeds that optimize a certain animal's energy, protein, mineral, and vitamin requirements.

Most modern livestock producers rely on a computer algorithm known as "least-cost feed formulation." These programs use mathematical models and linear programming to take into account the costs of various feed ingredients and optimize diet formulations to meet animals' nutritional requirements at the lowest possible cost.

While these formulas serve as guidelines and approximate a general understanding of the nutritional availability of various feed ingredients, in reality digestibility and availability can vary depending on an animal's genetics, and on factors such as how the feed was processed and on weather conditions during harvest.

Fortunately, innovations in animal nutrition have yielded tools such as enzymes that improve the digestibility of various feed ingredients, thereby increasing nutrient availability and reducing batch-to-batch variability. A natural enzyme feed additive distributed by BRI, for instance, increases the digestibility of protein in animal feed.

As animal nutritionists better understand the nutritional requirements of livestock and how to formulate more cost-effective complex diets, they will be able to "dial-in" specific feed enzymes to boost digestibility and, as a result, improve animal performance, either through higher meat yield or better feed conversion.

2. Breeding and reproduction

Farmers have been using selective breeding techniques to bring about desirable traits in livestock for hundreds of years. Starting with simple visual assessments and size and weight measurements, then moving on to sophisticated tools that can measure biodiversity, detect inherited diseases, and predict genetic potential, innovations in livestock reproduction have led to dramatic improvements in animal health, welfare, and productivity.

Meanwhile, other innovations such as artificial insemination and embryo transfer techniques have made it possible to rapidly distribute these genetic improvements throughout the animal production chain at less cost.

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Consider that, as a result, dairy cows today produce on average 50 percent more milk than cows milked in the 1950s. Or that broiler chickens eat a third of the feed originally required to produce a kilogram of breast meat, yet take only a third of the time to reach market weight compared to birds from just a few decades ago.

3. Disease management and health

Animal diseases have huge effects on nations' economies and on public health. Eleven out of the 12 major global disease outbreaks in humans over the last decade, including bird flu and "mad cow" disease, were from zoonotic agents (diseases that can be transmitted from animals to humans and vice versa), noted the National Research Council in their 2005 report, Animal Health at the Crossroads: Preventing, Detecting, and Diagnosing Animal Diseases. Each time, costs and pain accumulate as people are hospitalized, animals are culled, import bans are implemented, and demand for livestock products drop.

Again, fortunately, innovations in animal health have led to new methods of diagnoses, prevention, and disease control and management. The jury's still out on whether giving farm animals antibiotics will bring about the emergence of "superbugs" that are resistant to multiple drugs, but with the FDA tightening its rules against antibiotic use in the U.S., more research funds are being committed to viable alternatives.While enzymes are not a direct replacement for antibiotics, natural feed enzymes that help improve feed digestibility could naturally aid gut health, translating to bigger, healthier animals that are less susceptible to disease.

Improvements in animal nutrition, reproduction, and health have mostly been driven by scientific and technological innovations. There is no doubt they will continue to play a big part in meeting our world's rapidly growing demand for livestock products.

INNOVATIONS IN AGRICULTURE AND OUR ENERGY FUTURE

Food isn't the only resource that, if not sufficiently replenished, will set in motion a global crisis as the world's population reaches 9.3 billion by 2050. Energy is another.

For decades, we've relied on fossil fuels to power our way of life. We burn coal and gasoline to run our factories, our homes, and our cars. But as we all know, the earth took millions of years to produce these energy sources; they're non-renewable, exhaustible, and unsustainable.

It is within this context that countries all over the world are working to harness alternatives. Most of us are familiar with solar, wind, and hydro power, but perhaps less so with energy sources produced in massive quantities by the agriculture industry. Fortunately, this is changing as initiatives such as the 4F Challenge provide leadership, catalyze debate, and rally influential stakeholders around the value of forestry and farming not just for food and fiber, but also for fuel.

In the last two sections, we talked about how innovations in crop science and livestock production are taking place to help prevent a food crisis. Now, we'll look at agriculture-powered innovations that are likely to play a significant role in the future of energy production.

Energy through direct combustion of biomass

The International Energy Agency predicts that the bio-energy sector will experience significant growth over the coming decades, with biomass accounting for up to 30 percent of the global energy mix by 2050, up from 10 percent today. Biomass already accounts for roughly three-fourths of our renewable power supply.

Biomass is the general term for residues derived from plant and animal materials. It's the most abundant organic matter on earth. What's commonly considered waste—rotting trees, yard clippings, leftover crops, wood chips, municipal waste, livestock manure—can actually be used to generate electricity, fuel, and heat. (Just think about the last time you warmed yourself in front of a wood burning fireplace.)

Biomass can be converted into energy in three ways: (1) By using direct combustion to produce heat, (2) by using microbial fermentation (e.g., alcohol fermentation or anaerobic digestion) to generate alcohol or natural gas, and (3) by using chemical processes (e.g., transesterification) to produce biodiesel.

There is a viable industry dedicated to using direct combustion to produce biomass energy. Trucks, rails, or barges collect waste from factories and farms and bring it to biomass power plants, where the biomass is burned in industrial furnaces. The heat and steam this process generates is then used to power generators and turbines.

Energy through microbial decomposition and biogas production

Anaerobic digestion, or fermentation, is a natural bio-process. It uses microorganisms to decompose biomass anaerobically to produce biogas, a form of natural gas or methane. By simulating and accelerating this process, scientists are able to harness the biogas as an energy source.

An example of anaerobic digestion in action is the use of landfills to collect natural gas that's produced as bacteria breaks down the biomass in waste products. For instance, as much as 50 percent of the energy needs of the BMW auto plant in Spartanburg, SC are met with natural gas that comes out of a nearby Palmetto landfill. The gas travels 9.5 miles by pipeline to the BMW factory, where turbines convert it to electricity.

Most of us are familiar with solar, wind, and hydro power, but perhaps less so with energy sources produced in massive quantities by the agriculture industry.

A similar thing can be done on farms that raise livestock. In Yadkinville, NC, farmer Lloyd Bryant installed a waste-processing system that uses bacteria to anaerobically break down hog manure in giant containers and then burns the resulting biogas to generate electricity. It also converts toxic ammonia into forms of nitrogen that can fertilize crops. This system produces enough energy to power itself and five of Bryant's hog barns.

Anaerobic digestion was the process that BRI co-founder Jason Shih was using when he discovered the enzyme that forms the basis for BRI's enzyme products, Versazyme® and Valkerase®. At the time, Professor Shih was developing an innovative thermophilic poultry waste digester to generate power as part of his research on poultry waste management at North Carolina State University.

In the next section, we will shift our focus from biomass energy innovations to biofuel energy innovations. The best known of these is ethanol, a liquid fuel that can be blended into gasoline to power vehicles. We'll discuss two types of bioethanol (corn ethanol and cellulosic ethanol), as well as biodiesel (a common end product of a chemical process called transesterification).

CORN IN YOUR CHEVY, GRASS IN YOUR FORD, ALGAE IN YOUR TOYOTA

Three hundred years ago, wind (e.g., windmills) and water (e.g., ships and water wheels) powered our machinery. Animals pulled our transport vehicles. Burning wood chips and sawdust cooked our food. You could say that before the Industrial Revolution, there were no "alternatives" for energy—it was wherever and however you could get it.

Then we figured out how to use fossil fuels on a massive scale. Rich in concentrated energy, coal and oil built the world that we know today. Unfortunately, they're not renewable—at least not in our lifetime, or even our great, great grandchildren's lifetimes. They're called fossil fuels precisely because they formed as dead plants and animals fossilized over millions of years.

Due to the challenges associated with finding sustainable sources of oil as well as the environmental impact of burning coal, there is a growing interest in developing alternative sources of energy. In the last section of this white paper, we talked about how the agriculture industry is driving energy innovation by leveraging the massive quantities of biomass it produces. Biomass can be converted to energy either through direct combustion or anaerobic digestion.

> ***If we want to prevent a global crisis, we'll have to commit long term to finding sustainable forms of energy. The good news is that we now have the technology to harness them more efficiently.***

Now, we'll look more into innovations in biofuels such as bioethanol and biodiesel.

1. Corn ethanol

The last time you filled up your car at a gas station, you might have noticed a sign that says, "May contain 10% ethanol." Ethanol is a liquid biofuel that's blended into gasoline, usually up to a 10 or 15 percent level, and is the same type of alcohol you'll find in a bottle of beer. It can be made from sugar cane (in Brazil); starchy crops such as potatoes and corn; or from wood, grass, and other inedible plant parts. Most of the bioethanol in the United States is derived from corn.

It's relatively easy to produce corn ethanol. Just as in production of alcoholic beverages, the starch found in corn kernels is easily broken down by yeast fermentation into smaller units of sugar molecules (glucose), which are then further converted into ethanol as part of the metabolic process. The goal is to eventually replace a third of the United States' oil supply with bioethanol by 2030, but there's considerable debate over whether corn ethanol is sustainable. First, the bio-conversion process is not cost effective, and a net input of coal or natural gas-derived energy is required to power it.

And second, growing more corn for fuel would leave less land to grow corn and other crops for food and feed, which could affect grain supply and food prices.

2. Cellulosic ethanol

With cellulosic ethanol, there's no food versus fuel debate. Cellulose is inedible. We can find it in nearly every plant, tree, and bush in the world—including in crops we're already growing. And because cellulosic feedstock contains more energy than corn feedstocks, it requires less crop land than corn for equivalent energy. It can also be grown on non-arable land.

Unfortunately, it's more difficult and expensive to convert cellulose to ethanol. It has the same type of sugar molecules as starch, but they're bonded differently, as well as tightly packed and wrapped in lignin and hemicellulose, and as a result, are less degradable and more difficult to convert into ethanol.

Several government and industry initiatives have been launched to bring cellulosic ethanol commercialization up to speed. The Food, Conservation, and Energy Act of 2008, for instance, provided for grants covering up to 30 percent of the cost of developing and building demonstration-scale biorefineries for non-corn-derived biofuels. Meanwhile, biotechnology firms like Novozymes are developing enzymes that can cleave chemical bonds in multiple types of cellulosic feedstocks.

3. Biodiesel fuel

Unlike ethanol, which is currently just a petroleum additive, biodiesel can be used in pure form as a replacement for petro-diesel given a few engine modifications. However, it's more expensive, so blends varying from 2 to 20 percent biodiesel are more commonly used.

Biodiesel is typically produced by way of transesterification. That's a chemical process that converts the triglyceride form of fatty acids in plant oils or animal fats into the methyl esters form, which is more volatile and combustible.

One growing area of research in biodiesel production is focused on algae, a group of aquatic and photosynthetic organisms with remarkably strong metabolic capacities. Because algae don't have roots, stems, and leaves, they don't have to produce cellulose, and thus grow much faster than terrestrial plants. They can also produce oil that is stored in a large portion of their cells.

San Francisco-based alternative energy company Solazyme grows microalgae in fermentation tanks, while Sapphire Energy grows theirs in football field-sized ponds in New Mexico. After years of military and commercial application testing, both firms are building large factories and farms with the goal of transitioning from low volume to commercial scale production. The challenge is to produce enough algal fuel so it can compete with petro-diesel on price.

Perhaps bioethanol, biodiesel, and other types of biofuels won't ever completely replace coal and oil. But the point is that we can't afford to put all our eggs in that one basket. If we're going to prevent a global energy crisis, we'll have to commit long term to finding alternative and sustainable forms of energy. The good news is that now we have the technology and innovations to harness them more efficiently.

INNOVATION IN COMPANIES, COUNTRIES, AND AGRICULTURAL ECONOMIES

We began this white paper by pointing out that the term "innovation" has become somewhat of a tired and overused term. It's been used to describe everything from inventing a product, to extending a product's scope and application, to simply coming up with a new or different idea—all of which, while true, dilute the real value that innovation has brought and continues to bring to our lives.

We defined innovation, in the broadest sense, as "applying new thinking to solve existing problems." We argued that a novel idea or method (an invention) only becomes innovative after it has been used to successfully address a problem or need.

Referring to concepts presented in Clayton Christensen's seminal book, *The Innovator's Dilemma*, we also differentiated between two types of innovation: sustaining and disruptive. Sustaining innovation provides consumers with incremental value (e.g., a new car model with better gas mileage), while disruptive innovation disrupts the market for an existing product (e.g., LCD technology versus CRT technology for television and computer monitor displays).

We explained that large companies are more likely to come up with sustaining innovations, while startups and small companies are more likely to produce disruptive technologies. Mature businesses generally have less flexibility and a lower tolerance for risk. They don't want to rock the boat (especially when the boat's working just fine), so they devote most of their efforts to improving on past successes.

Startups, on the other hand, typically start with nothing—no blockbuster products, no legacy systems, and thus have less at stake. As a result, they are less constrained by conventional thinking and more receptive to taking on risk, which helps drive innovations that eventually render existing solutions obsolete.

Characteristics of innovative entities

Subsequent sections covered some common themes we've observed among innovative entities, from small companies to entire countries. First, we encouraged entrepreneurs to foster a culture of innovation in their organizations by adhering to five principles: open communication, fit within an ecosystem, teamwork, fair competition, and creating positive change.

We then expanded from the five characteristics of innovative business cultures to characteristics of countries that embrace innovation, namely a strong scientific and technical infrastructure, diversity, a relatively young population, intellectual property protection, and a culture that encourages experimentation and risk-taking.

Among these characteristics, we focused in a bit more on diversity, noting that while there are many sides and perspectives on the issue of immigration in the United States, it's clear that this country's history of innovation has benefited from immigrants from all over the world. For instance, close to 40 percent of all Fortune 500 companies were founded by immigrants or children of immigrants.

We noted how our immigration system turns away many immigrants that want to start businesses in the U.S., forcing them to take their ideas and skills somewhere else. Then we explained how a more strategic immigration policy would allow immigrant inventors and innovators to contribute not just to their adopted countries but to their home countries as well.

Agriculture-powered innovations

The last few sections focused on an area of particular interest to our readers: innovation in the agriculture industry. We pointed out that farmers have been innovating for hundreds of years and highlighted what we thought were some of the best farming innovations of the last century.

We hope you enjoyed our white paper on the topic, and that as a result, you are able to appreciate, initiate, or facilitate more innovations in your respective organizations and communities.

In the field of crop science, we covered the three-point hitch system, which increased farming efficiency by making every tractor implement, such as a ploughshare, part of the tractor. We also discussed dwarfing strains of wheat, which dramatically increased grain production by enabling agronomists to produce plants that were less susceptible to damage and that devoted more energy to filling the grain. Finally, we talked about genetically modified crops, which allowed farmers to grow crops with desirable traits that can't be achieved through conventional breeding techniques.

In the area of livestock production, we discussed enzymes that improve the digestibility of feed, leading to higher meat yield or less feed for the same amount of meat; sophisticated breeding techniques that result in genetic improvements in livestock, so that dairy cows today produce 50 percent more milk than their 1950s counterparts; and new methods of prevention, diagnosis, and disease control and management in animals.

Finally, we looked at agricultural-powered innovations that lead to improvements in energy production. Generated in large quantities by the agriculture industry, biomass (the general term for residues derived from plant and animal material), now accounts for majority of our renewable power supply. Together with solar, wind, and hydroelectric power, it's expected to play a significant role in our energy future.

Meanwhile, we explained how biofuels such as ethanol are derived from corn and cellulosic feedstock and blended with gasoline to power vehicles. And how biodiesel, produced when fatty acids in plant oils and animal fats are bonded to alcohol, is combined with petrodiesel or sometimes used as a complete alternative with few engine modifications.

Overall, we emphasized how innovations in agriculture have played a critical role in the world's food, fiber, and fuel production.

Although we chose to pay special attention to the agriculture industry, we want to leave you with the idea that innovation is necessary for the sustainable growth of every business in every industry. We hope you enjoyed our white paper on the topic, and that as a result, you are able to appreciate, initiate, or facilitate more innovations in your respective organizations and communities.


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