9 | A GLANCE AHEAD

Although this is a history book, faculty member Tony Grift asked that it include some predictions as to what lies in the future, especially as the future relates to the ABE department. The ABE Futures Committee/Council thought this was a good idea. Accordingly, the decision was made to include a chapter entitled "A Glance Ahead." A number of people were invited to make predictions out to the year, 2025, i.e., 15 years beyond the publication year of the book. Tony Grift worked with Kaustubh Bhalerao, Steve Eckhoff, Al Hansen, Prasanta Kalita and Yuanhui to write a combined prediction. Members of the Futures Committee/Council, Carroll Goering and Roscoe Pershing, wrote predictions. Finally, three undergraduate students contributed predictions. They were Andrew Gentile, Kim Keinecke and Patricia Paulausky. These predictions are presented in the paragraphs below.

A Glance Ahead

Grift, Hansen, Kalita, Zhang, Bhalerao, Eckhoff

The form, shape and size of the department of Agricultural & Biological Engineering in 2025 in terms of teaching, research and extension depends on many factors and is not easy to predict. To limit the scope, assume that in AD 2025, the department will still be an autonomous unit within the University of Illinois having the word Agriculture in its name, committed to addressing global challenges through research, education, and outreach. Following are some global challenges to be addressed, which new technologies will be influential, and the strategy needed to reach Departmental goals.

9.1 Global challenges

The ABE department in 2025 will still be focused on major challenges facing humanity. Food security is crucial since the global population is projected to grow to 9 billion people by the year 2042. We are concerned with securing enough food and also about the safety of the food from deleterious activity. Much of the U.S. food chain is vulnerable to tampering by terrorists. We need to develop monitoring and security systems to assure the food is not tampered with before, during and after production. Most processors have developed security systems for their production facilities, but with over 15.7 million km2 of arable land in the US, it will be difficult to provide security at the level found in processing plants. Agricultural engineers will be taking the lead on providing technology, processes and products for a secure global market.

Secondly, in light of the limited fossil fuel supplies and the influence of their use on climate change, producing energy from renewable sources will become imperative. While it is reasonable to assume that some biomass will need to be processed to achieve the demand for transportation fuels, it is not clear what percentage of the available biomass will be converted. The costs are so high for collecting, storing and transporting biomass that corn to ethanol will remain the predominate pathway to biofuels. The importance of genetic engineering on increasing corn yields cannot be over emphasized. If corn yields can keep up with demand for transportation fuel, biomass may be relegated to non-portable fuel.

Thirdly, the impact of Agriculture on the environment must be addressed and sustainability must be high on the agenda. For instance, there are currently seven weeds that have been designated as 'glyphosate resistant', an alarming trend indeed.

Fourthly, Water resources will become increasingly scarce due to inefficient water usage, climate change and bioenergy production, and new and effective ways will be needed to deal with this issue. Much of the ground water used in bioenergy production is cooling water and given sufficient value to water, there are mechanical cooling methods which may be usable.

In the higher education arena, major challenges also exist for the department in equipping students with high quality and relevant knowledge and skills to be able to practice in their chosen profession. The National Academy of Engineering advocates qualities such as communication and teamwork skills, flexibility, and creativity in their vision for the "Engineer of 2020" . ABET specifies that engineering programs must ensure that their students demonstrate multidisciplinary teamwork, communication skills, ethical and professional responsibility, and an understanding of engineering in a global and societal context. From a broader perspective, the Association of American Colleges and Universities has identified educational outcomes for all students in higher education that are attuned to an increasingly global society, including intercultural competence, local and global civic knowledge and engagement, and the application of knowledge to new settings and complex problems .

9.2 Key technologies and their roles

The department will be developing engineering solutions for the challenges as mentioned. Continuing along the current path, we will develop technologies to make engines run cleaner, more efficient and develop sustainable bio-fuels to power them. We will continue to use systems approaches to optimize multiple agent operations. Corn fractionation processes will become more efficient, providing new and improved end-use co-products. While the processing amount will continue to grow, it is our view that the size of processing facilities may be reduced to be more local and integrated with other processes or agricultural systems.

Previously, new technologies such as GPS, GIS and sensing technologies have spawned the age of Precision Agriculture. The definition of Precision Agriculture now includes Automation Technologies such as wireless communication and robotics. We will continue to develop autonomous robots for scouting the fields for insects, disease damage and crop stresses. We will pursue the concept of multiple robot systems that communicate among themselves, employ internet databases for weed recognition and control, and most importantly apply Mendelian principles to 'evolve' the flock to optimal performance. Robots will also be used in specialty crops such as peach, apple and grape, where operations such as thinning and pruning will be conducted by robots. In the area of machinery, we will design feedback sensor-based equipment to deliver seeds, fertilizers, and pesticides in exact amounts with very high uniformity. We will also develop crop sensors, to be used to monitor insects, diseases, and weeds as well as soil sensors to monitor compaction, nutrient levels, and potential leaching. We will develop high throughput Phenotyping methods, since currently, sequencing of genomes is already affordable and fast, but technologies allowing, for instance, assessment of corn root complexity are severely limiting agronomic research.

Research into new generations of biofuel is rapidly expanding and can be expected to continue strongly over the next two decades. Our department's portfolio of biofuel research is well posed to address key areas of interest, namely production of biomass, including algae, and its conversion into both solid and liquid biofuels. Currently, the department has a BP funded program within the Energy Biosciences Institute created, which began in 2008 that investigates the engineering required for the production of biomass feedstocks that can be converted into biofuel. The program has the potential to continue for another seven years, by which time some crucial answers to the challenges of growing, harvesting and delivering sufficient biomass to bio-refineries will have been provided. Another example in the department's biofuel research portfolio is the Environment-Enhancing Energy (E2-Energy) program initiated in the Bioenvironmental Engineering area, which focuses on a broad vision of converting biowaste and algae into biocrude oil, capturing carbon and cleaning water. Initially the biowaste is separated into liquid and solid streams with the liquid stream being used to provide nutrients for algae growth and the biosolids being converted into biocrude oil via hydrothermal liquefaction (HTL). Simultaneously the algae are separated from the relatively clean water and are added to the bio-solid stream. The resulting biocrude oil can be refined by traditional hydrocarbon-based processes into gasoline, diesel fuel and other products.

The Soil and Water Resources Engineering Division in the Department has been engaged in pioneering research in water quality, nonpoint source pollution, erosion control, drainage, water management, and irrigation. Envisioning the need for more production to meet global food demand, we are emphasizing intense research and educational needs in the area of water production and water management. Water is essential for all socio-economic development and for maintaining healthy ecosystems. As population increases and development calls for increased allocations of groundwater and surface water for the domestic, agriculture, and industrial sectors, the pressure on water resources intensifies. Today, agriculture accounts for 70 percent of all water use globally, up to 95 percent in several developing countries. To keep pace with the growing demand for food, it is estimated that 14 percent more freshwater will need to be withdrawn for agricultural purposes in the next 30 years. Water scarcity threatens the sustainability of the natural resources base. Addressing water scarcity calls for multidisciplinary approach to water resources management without compromising the sustainability of vital ecosystems. Protecting and restoring the productive soils and the ecosystems that naturally capture, filter, store and release water, such as rivers, wetlands, and forests, is crucial to increasing the availability of water of good quality. With trends of climate change patterns, our future work will continue to examine current practices and develop innovative soil and water management practices for significant global impact.

A significant amount of agricultural land in Illinois and other Midwestern states (and many other parts of the world) is artificially drained. For almost all of the approximately 160 years of documented drainage improvements in Illinois, the emphasis has been on improving crop production. However, the last 20 years have seen an increasing focus on the effect of drainage on environmental water quality. This work has been subsumed into a larger national effort to improve water quality from drainage systems. The Agricultural and Biological Engineering at the University of Illinois continues and intensifies research in investigating water quality problems associated with subsurface drainage. Future research emphasizes the need to define solutions to these problems. Our future activities will continue to emphasize long-term watershed research involving stake holders' active participation to understand and overcome barriers for implementing agricultural management practices that reduce nutrient and pesticide transport in surface and subsurface flows, while improving crop production. On-site remediation techniques for nitrate-N contaminated tile drain water with water table management and bioreactors are currently being evaluated. Our future activities will include developing large-scale high-efficiency bioreactors for on-site remediation of contaminated water. Future research and educational activities will need to be continued for reduction of microbial pathogens from receiving water systems for safe drinking water supplies. New educational tools need to be developed and implemented so that our future work force can effectively manage our water resources and sustain food production.

9.3 The evolving role of biological engineering

A 2009 report by the National Academy of Science entitled, "A New Biology for the 21st Century" details the increasing role of life sciences combined with biological engineering in global problems related to agriculture, environment energy and health. To tackle the challenges of improving food security, energy independence, environmental sustainability and individualized healthcare requires commensurate progress in analytical frameworks and design methodologies specific to biological engineering. Inasmuch as every engineering design methodology is based on its corresponding engineering science (e.g. mechanical engineering is based on mechanics, chemical engineering on chemistry and biotechnology on biochemistry), biological engineering design must be based on the science of biology, more specifically, on evolution and ecology. Clearly the current definition of biological engineering falls far short of this vision as few in the biological engineering community recognize this as the future of biological engineering. There are, however, glimmers of an emerging, comprehensive philosophy of biological engineering on the horizon. For instance, our ability to produce biomolecular data (genomic / transcriptomic / metabolomic) for single species as well as collections of species continues to rise at a super-exponential rate. Systems biology is a framework that aims to organize and integrate this incoming data stream into creating a computational picture of the living world around us. Synthetic biology on the other hand provides powerful fabrication tools to design and create genetic molecules with functions and behaviors not seen in nature. Together, these new scientific disciplines provide the foundational tools to reprogram life itself. It is expected that these tools will be fundamental to probe questions about the biosphere, its role in developing structured ecosystems and the evolution of organisms and species with changing environments. As a result, we will expect to see great leaps forward in developing climate change-resistant agriculture, ecosystems designed to maximize their bio-geo-chemical services, tools to quantify environmental impacts of contaminants, natural and anthropogenic as well as fundamental shifts in our understanding and management of health and pathogenesis in humans as well as organisms of agricultural and industrial importance.

Looking to 2025, we expect the world will have come to rely on biological engineering in every facet of living systems, as we have come to rely on information technology and electrical engineering today. At the heart of this (r)evolution will be the technologies and methodologies developed in our Department.

9.4 Strategies

As described in Chapter 1, in 2004 the department went through a process of redefining its mission, vision and its core values. It identified 15 domains pertaining to its scope of activity in agriculture, food, environment and energy as well as four competencies of automation, culture, environment and systems. It is likely that at least the department's mission, vision and core values will change very little between now and AD 2025. We are AD2010 the number one department in undergraduate as well as graduate education. Our department will continue to educate leaders that are capable of leading the development to deal with the challenges mentioned above. In addition the 15 domains overlap substantially with these global challenges, which suggests that the department's research, teaching and extension efforts are already aligned with addressing these challenges.

Collaboration with companies is challenging since companies and academia have very different strategies for success. However, there is a need to create working relationships with companies to provide a workforce for them in the future and in turn employers for our graduates. There is also a great need for collaboration among departments in the college of ACES and Engineering. We need to foster real collaboration between departments in ACES, and Engineering since true innovation takes places where departments overlap. We also need to educate our students to be able to work in multi-disciplinary and multi-cultural environments, and develop a reward system that recognizes the hurdles but also the payoffs of true multi-disciplinary work.

Factors that will influence the education of students as we approach 2025 will include advances in technology with particular reference to ubiquitous inter-communication and computing, practicing engineering in a global context, and applying engineering to the full spectrum of the biological domain from nano scale to ecological systems.

We have to be committed to solving real problems, and not revert to "Picking the low fruit", or following the road most easily traveled. President John F. Kennedy said it best in 1963: "We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard".

The changed US energy mix

Carroll E. Goering, Emeritus Professor, 2010

During the past 15 years since 2010, changes in a number of technologies have led to a substantial change in the US energy mix as shown in the table below.

	Percent of total energy	
Energy source	2010	2025
Petroleum	37	20
Coal	23	27
Natural gas	24	27
Nuclear	8.5	10
Biomass	3.9	10
Hydroelectric	2.5	3.0
Geothermal	0.35	0.4
Wind	0.55	2.0
Direct solar	0.09	0.6

Petroleum was the most critical energy resource in 2010. Petroleum production in the US was declining and over 60% of consumption was being imported, often from countries whose citizens used the petroleum monies in ways that were harmful to the US. While the US population was growing at just under 1% annually, per capita energy consumption was declining enough to hold total annual US energy consumption nearly constant over time.

In 2010, coal was plentiful in the US, but environmental concerns were causing a decline in the use of this fuel resource. The US also had good supplies of natural gas, although this fuel was not at plentiful as coal. Nuclear energy use had reached a plateau and no new nuclear energy plants had been built in several decades. The remaining sources constituted only 7.4% of the total energy sources in the US. The challenge in 2010 was to reduce petroleum imports by reducing the percentage of the total energy supplied by petroleum.

The main focus in reducing petroleum consumption was on transportation as, in 2010, it consumed over two thirds of the total petroleum use. Limited progress in battery development kept battery electric vehicles from extensive use. However, development of plug-in hybrid electric vehicles (PIHEVs) greatly increased the amount of travel possible from each liter of fuel. Moreover, research at the University of Illinois and other places led to production of cellulose-based liquid fuels to power PIHEV engines and led to a more than 250% increase in the portion of total energy supplied via biomass. As a result, the amount of petroleum used for transportation fell by over 40%. While use of electric energy use in vehicles increased, much of that increase was provided by increased use of nuclear power as more nuclear power plants again began coming on line. Also, development of clean coal technology allowed coal use to increase. Use of solar electric increased over 600% and wind energy increased more than 300% since 2010, but both began at such low levels that their contributions to the total were still small.

The US also increased domestic petroleum production through increased exploration and by conversion of coal and shale to petroleum-like fuels. Coupled with increased production, the decreased consumption of petroleum allowed the US to reduce total energy consumption and virtually eliminate petroleum imports. Great increases in petroleum consumption by India and China kept petroleum prices high, but the decreased US petroleum imports led to a large reduction in the US balance of payments deficit and more than offset the cost of the research and development that made the reduced petroleum consumption possible.

A Glance Ahead

Roscoe Pershing, Emeritus Professor (2010)

Technology will continue to develop at an accelerated pace. Many changes will occur that will frighten some and provide opportunities for others. Engineers must seize these opportunities and use them to make the world a better place. Early adopters will benefit most. Electronics and computers will continue to improve and agricultural and biological engineers will utilize these developments to improve all aspects of agricultural and biological processes, equipment and products. Probably, biological breakthroughs will be the most significant in the future since that branch of highly-complex science has been a little slower to develop – thought by some to be the last frontier in science!

Society will change, too. The supply of safe food, clean water, and a sustainable environment will present even greater challenges ahead. The role for ABE will be greater than ever and we must embrace it and respond to it. More remote sensing and automation will be required. Vehicle guidance may lead to remote or fully automated control. Biological sensing and biological design will lead to new fields of endeavor for agricultural and biological engineers. With the growing population, the challenge to feed the world safely with sustainable resources will present a major challenge.

I predict that by 2025, we will be doing more with hand-held electronic devices. Cell phone, computer, and camera, will combine with TV, and sensors and automation control of many processes – all within the same hand-held device. Video conferencing among several persons will be done by cell-phone technology. Cell phones will switch from towers to satellite transmission for better, uninterrupted service and provide reliable service to remote, rural areas. This will interface with or also contain GPS signals and equipment control that can be monitored or set from hand-held devices even when far away from the actual operation being controlled. These individualized hand-held devices will enable us to communicate, control and manage more activities and operations remotely with greater skill and timeliness – giving us the greatest productivity and efficiency we have ever known. At the same time, the nature of social communication, as we know it today, will certainly become a new and major challenge – from face-to-face group discussion to hand-held electronic device video conferencing.

Our charge will be to apply the new and relevant technology to agricultural and engineering-related enterprises to continue to improve the useful technology and lifestyle of the world and its inhabitants!

The good news is that the ABE Department is well-positioned to take a strong leadership role in all of these developments.

Best wishes for continued leadership in 2025!

An article from the San Francisco Chronicle, Sunday August 31st, 2025

Andrew Gentile, undergraduate student in 2010

California just doesn't seem like the Golden State any more. Along with the financial troubles that have plagued Sacramento since the start of the new millennium, Californians have experienced some of the hottest temperatures on record this summer. With less than average rain totals last season, the Central Valley's citrus and nut crops are suffering. Furthermore, farmers and cities alike have been struggling with the federal government to secure more money to protect the state's resources after terrorism struck the Central Valley two years ago. A glimmer of hope arrived yesterday as the government finally approved a plan of action and I certainly believe a brighter future is ahead for the United States as California serves as a model in deploying new security measures and utilizing revolutionary technology to secure its livelihood of agriculture that the rest of the country depends on.

As an undergraduate at the University of Illinois at Urbana-Champaign, I came home to Gilroy for summer break and I used to enjoy the five-hour drive south down Interstate 5 through the Central Valley with my family to visit my brother at the University of Southern California in Los Angeles. En route, I convinced my parents to pull off to the side of the road to gaze at a stretch of the 444-mile-long manmade river that supplied water to some 25 million California residents and countless acres of thirsty crops. People like me could park their cars next to the aqueduct and marvel at this impressive feat of civil engineering. However, these days are gone as of June, 2023. California tightened security along the aqueduct when terrorists, all working for biotechnology companies in San Francisco, dumped a wide variety of biological agents into the aqueduct including Cryptosporidium, a protozoan parasite that caused diarrhea in thousands of Californians and was responsible for countless deaths.

The water filtration facilities already in place destroyed many of the agents present in the terrorists' toxic cocktail. On the other hand, the water from the aqueduct was not decontaminated prior to the irrigation of crops, which led to the pathogens taking residence in the fields surrounding the aqueduct. The leachate from the contaminated soils found a way to enter the drinking water of millions of people. In order to set California on the right track, scientists are faced with two challenges: How to prevent biological agents from entering fresh water supplies again, and how to clean up the mess in the fertile soils of California.

Research from the UIUC on the movement of Cryptosporidium has helped to create computer models that can track how the organisms travel through the soil, allowing for scientists to determine precise locations of contamination so that clean up efforts are concentrated in the proper areas. Information from the United States Geological Survey and the Natural Resources Conservation Service has aided us in our models of soil erosion. These visuals are giving cleanup crews invaluable information. The federal government has also stepped up to the plate by giving grants to private biodefense contractors, thus creating thousands of jobs to design and construct new security measures to detect and track movements of particles and toxins in water supplies throughout the nation.

My hope is that advances in biodefense will wipe the tarnish off the Golden State by stimulating the state's economy, protecting our precious water resources, and increasing the productivity of agriculture not only in California but also throughout the United States.

Andrew Gentile is a bioterrorism specialist at Lawrence Livermore National Laboratory in Livermore, CA. He is a graduate of the University of Illinois at Urbana-Champaign and is a Bay Area resident.

A Glance Forward: Autonomous Vehicles to Poke-less doctor visits

Kimberly Heinecke, undergraduate studet

In 2010, you have to get in your car, drive it to the doctor, and get blood drawn. By 2025, things have changed drastically. You no longer have to drive yourself to the doctor or be stuck by a needle. In 2025, autonomous vehicles and poke-less doctor visits will exist.

Through Agricultural and Biological Engineering, both of these painless and safer ideas will come true. Autonomous electric vehicles, supported through GPS and smart road technology, where vehicles are able to talk to each other as well as monitors in the road, will provide a safer alternative to human driving. Autonomous vehicles will only require the owner's fingerprint to turn on and voice command to give instruction where to go. The vehicles will automatically take care of parking, safe entry and exiting of the passengers, and powering up. There will be known hot spots of wireless charging which the car will recognize; owner's will no longer need to worry about fueling up.

When the patient arrives at the doctor's office in 2025, he or she will no longer need to be poked with a needle in order to get a full patient work up. Through breath and urine analysis as well as a walk through scanner, the patient will be able to see the status of his or her health. Agricultural and Biological Engineers will make this technology possible through identifying certain proteins and enzymes relate to each disease. Needles are only needed when starting an IV, this single use of needles will provide a lessened chance of infection.

Understanding animal behavior

Patricia Paulausky, ABE undergraduate student in 2010

It may be difficult to imagine that a mere 15 years ago Engineers in the field of Animal Housing and Environmental Control were not so fortunate as to have some of the great technological luxuries that we today take for granted. Try to take yourself back to a time when motivational and preference testing were two seemingly simple concepts that could make an engineer cringe – a time when behavioral analysis within these studies was not as effortless as connecting to your computer. In fact, it would have involved a comprehensive review of footage by hand which could take days or weeks – if you were lucky. Today, much time, unnecessary professional collaborations, human error, and not to mention strife, has been eliminated from animal housing and environmental control studies. With the use of computer aided animal behavioral analysis software, engineers have at their disposal a tool which can be used to accurately assess the presence of behaviors indicative of stress or contentment in animal test subjects within a timely fashion. This software is guided by patterns of motions and sounds exhibited by the test subject.

It has been with the assistance of this software that Engineers have been able to expand the knowledge of agricultural animal preferences. Being able to accurately measure these preferences consistently across a variety of studies has been especially crucial in justifying agricultural animal housing, as well as optimal environmental and transportation conditions. It may seem strange now that just 15 years ago the field of animal production was battling the moral dilemma of caged vs. cage-free. This software has made it possible to expedite the data analysis of many of the preference and motivational testing that led to the scientific conclusions of this dilemma – as a result these studies have become more frequent and more accessible. In the case of housing, and similar matters, such as environmental preferences, the software has helped to revolutionize the way the animal agriculture industry makes decisions concerning the well being of their investment. Due to the industry's access to this advancement in knowledge of animal preferences, agricultural animals today are considered to be healthier, and more nutritious animal products are in greater abundance than just a few decades ago. In addition, the software has streamlined the way we observe animal behavior from speculation to scientific conclusion. Streamlining has helped to raise the standards of agricultural animal husbandry because now the field of animal welfare has a more substantial backbone of scientific behavioral data to stand on. Kudos to engineers of the past for paving our way into future discovery..