Mission 2050: Building Envelopes for the Future

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Take Home Messages

- Traditional agriculture's future will be viable if the environment (air, water), soil/land, energy and labour issues can be resolved.
- Building-omics, high performance building design, energy alternatives, advanced building materials and 5G technologies will allow new building envelopes to generate as much or more income than the products from animals housed inside it.
- Each farmstead will become its own rural economic incubator. Diversification of the farm enterprise will be a standard practice in the future.

Introduction

"The best way to predict the future is to create it" (P.F. Drucker). This quote is very relevant to the agriculture sector going forward. For the past 50 years the dairy industry has been guided by the 'make it happen' type people but for the next 50 years the industry will be transformed by visionary leaders who can take science and engineering from other industries and apply it to the tradition and art of dairy animal husbandry. Cow-side telemetry, genetics and nutrition advancements have greatly improved the health and welfare of animals, but it is now time for all the physical structures around them to attain the same level of sophistication.

The central issues that will greatly shape the industry in the future will revolve around the environment (air, water), soil/land, energy, labour and the evolving social contract with consumers. This paper will address some of the potential solutions to these issues by combining all the natural and physical resources on the farm with new technologies existing in other industries. The intent is idea generation and only covers some of the new technologies currently being evaluated.

▪ Challenges

"The greatest challenge in the 21st century will be the human-induced changes in the environment" (NRC, 2003). This, in combination with the recently released report by the United States National Climate Assessment (2018, https://www.globalchange.gov/nca4) and the United Nations (2017, https://www.ipcc.ch/) report from the Intergovernmental Panel on Climate Change portrays a very devastating effect of a changing climate on the economy, health and the environment. Extreme weather will increase crop failures, heat and cold stress and a crumbling infrastructure. The requirement to reduce greenhouse gas (GHG) emissions (methane, nitrous oxide, carbon dioxide) continues to challenge the agri-food sector. Manure storage and livestock facilities are generally net emitters of GHG whereas the farmland is mainly a sink for carbon dioxide (Sedorovich et al., 2007).

Air quality as judged by particulate matter (PM) is gaining more attention (Cambra-Lopez et al., 2010) principally $PM_{2.5}$. ($PM_{2.5}$ are the most dangerous dust particles that penetrate deep inside the lung). Wooten et al. (2015) measured PM downwind from beef feedlots and found pharmaceutically active substances that have the potential to elicit endocrine-modulating effects.

"Water is the most important nutrient for dairy cattle" (NRC, 2001). The escalating prominence of water as a nutrient over the years has clearly reflected the attention given to water as a diminished environmental resource. Water is generally assumed to be in abundance and is a very small cost relative to other essential dietary ingredients. However, fresh clean water is becoming a limited resource and wasteful water use has led to over-tapping of aquifers. Water-taking permits from groundwater and rivers for potable and irrigation use will be a variable cost, even on your own farmstead. Water right policy will be the norm in the future and the growth or expansion of the farmstead will be dictated by local water conservation authorities.

Soil/land is the greatest asset on a farm. However, unutilized nutrients fed to animals and fertilizers generally end up in the watershed causing other environmental issues. The soil microbes are changing and the organic matter is shifting; combine these with either drought and/or flash floods and production catastrophes will increase. Canadian famers will face nitrate and phosphorous, water and national emission ceiling directives as seen in other countries (Van Grinsven et al., 2016)

Energy is the pivotal point of productivity in all industries. Rural areas face the dilemma of power quality (transient voltage) and delivery through an antiquated hydro grid system.

Labour continues to be a challenge in the agricultural sector. Automation (10% and 6.8% of Alberta and Canadian farms, respectively, have automated milking systems; www.dairyinfo.gc.ca) and consolidation has reduced the number of workers. However, finding Canadian workers with the right skills and experience at the management level will be the principal challenge. Automation and technology will continue to shape the industry to a less labour intensive one.

ProAction has demonstrated that dairy farmers are agents of "responsible stewardship of their animals and the environment, and produce high-quality, safe and nutritious food for consumers", (https://www.dairyfarmers.ca/proaction). I would say that primary agriculture is the foundation of civilization. Just ask yourself: "What is the universal thought of the day? What am I going to eat?" Primary agriculture can be an influential player in tackling many of the social, environmental and economic issues facing civilization. It can address several of the "sustainable development goals" outlined by the United Nations (Figure 1).

Figure 1. The 2030 sustainable development goals as defined by the United Nations. https://sustainabledevelopment.un.org/?menu=1300

■ Ideations

The following blue-sky ideas address the previous challenges listed. These concepts may have immediate application or within a five or ten-year window.

Some may be more of a ‘cathedral’ build approach and expand over decades. The ideas will take advantage of all assets on a farm and integrate or loop them together.

New building envelopes will be the epicentre of multiple energy generation and storage systems and green water (roof-harvested rain water) capture. The building design will allow for the installation of a wind turbine within the roof of the building. Excess mechanical energy will be stockpiled as compressed air energy storage (CAES; Venkataramani et al., 2016) within the tubular frame. CAES can then be released to run pneumatic motors or a generator. The roof structure can also be used for direct CO_2 capture from ambient air. In addition, the roof can be equipped with solar thermal and solar photo-voltaic panels (Figure 2).

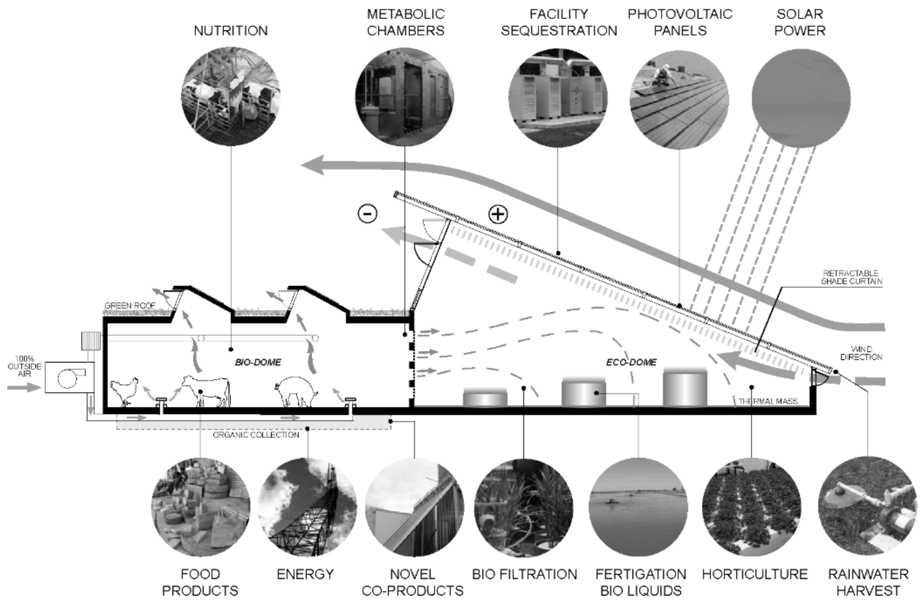

Figure 2. Examples of total resource capture and recovery.

Micro-turbines and fuel cells such as solid oxide, proton exchange, and microbial will convert chemical energy of fuel (natural gas) to electricity and high-grade heat. These units can be combined with wind and solar energy, and through these simultaneous energy generation systems, will allow for storage of electricity in advanced battery systems. The farm then becomes a service to supply energy to the grid or a micro-grid of adjoining farms. Wireless power transmission is advancing and with 5G batteries powered by concentrated wavelengths, electrical wire on lights and small devices will not be required. The high-grade heat can also be used for heating and cooling in other areas/components of the facility.

Green water (Chubaka et al., 2018) is easily captured; as well as capturing the water volume, the kinetic energy of rainfall from the peak to the eve can be collected. Captured water is then stored in a cistern or in bladders within the facility and used as insulation. Water is pumped continuously around the structure. Rain water can then be channelled to a sub-surface drip irrigation system to fields close to the facility or used to develop tree-lined fence bottoms for soil erosion prevention and odour control (Hernandeza et al., 2012). The high-grade heat from a micro-turbine or fuel cell can also be used to purify rain water for cleaning milking equipment.

The dairy and greenhouse industries in Canada are well established and have embraced automation and technology. Combining the two is obvious. The cow produces nitrogen, phosphorous, potassium, heat and CO_2 – exactly what plants need. Figure 3 shows the original concept of Mission 2050 to attach a 20,000 sq. ft. greenhouse to the side of the dairy barn. The greenhouse can be used as a starter house for high-value plants or complete grow-out. Nutraceutical type plants could be grown and fed back to the cows for value-added milk products. High-grade heat from the co-gen units (co-generation; creating electricity and heat from one unit) can be used in the greenhouse as well. Other novel plants could be wild flowers, herbs and spices. The greenhouse could also be used for vermiculture (worms), insects and heliciculture (snails).

Figure 3: Greenhouse attached to the dairy facility of the Mission 2050 conceptual project.

Future building themes inside of a new facility will focus around the four movements: animal, people, feed and manure movement. The cow also requires an effective thermal comfort environment. New ventilation designs that temper air and humidity include: top down ventilation, geothermal cooling beds, embedded, passive-solar walls; solar chimneys; and earth tubes. Earth tubes can be used in reverse to capture carbon. Advanced building materials such as plastic composites, artificial turf, carbon fibre and porous cement will greatly enhance the internal environment. Porous cement will allow for immediate separation of urine and feces reducing volatile organic compounds. Advanced dewatering systems (heat from co-gen units) and microwave (Srinivasan et al, 2016) treatments will allow for fragmented waste streams for land application or compost teas for algae growth and bio-fuel development. Nanoparticles attached to the waste components will have a time-release or release linked to an environmental trigger to minimize off-farm migration. Innovative technologies such as phosphorus and other elemental recovery systems will be standard (Zhang et al., 2015).

The internal facility must be designed to unlock the cow's senses (visual, tactile, olfactory, and auditory) to enrich her environment. The future dairy barn will have a smorgasbord of individual selections for heating, cooling, oxygenation, feedstuffs, stand-up mangers, light, and cleaning and grooming. Example of this is cooling zones (misting posts) instead of cooling the entire facility because each cow has her own effective thermal comfort primarily based on metabolic activity. The Glasshouse-Cow facilities of the future are designed to resemble the cows' natural environment with the capacity for cows to walk and graze inside a building. In addition, the building is covered with a transparent material to make dairy farming visible to consumers (Demeter et al., 2009).

The social contract with consumers will continue to resonate in the Canadian dairy industry. Other countries are more progressive with a sustainable dairy chain with goals such as improving energy efficiency and production (including climate-neutral growth of the dairy chain), reducing greenhouse gasses, improving cow longevity, reducing antibiotic use (animal health and welfare), maintaining a level of 75% of farms grazing, decreasing nitrogen and phosphorous leakage and ammonia emissions, and improving biodiversity (https://www.duurzamezuivelketen.nl)

▪ Conclusions

"When it comes to the future, there are three kinds of people: those who let it happen, those who make it happen, and those who wonder what happened', a thoughtful quote from J.M. Richardson Jr. Solving challenges of the environment (air, water), soil/land, energy, and labour will require a multi-profession, multi-disciplinary, collaborative approach. Getting researchers to gravitate to disciplines outside their expertise will be a task. Although, a number of these new technologies can be modelled, simulated and visualized through existing software programs to evaluate their metrics and productivity for agricultural facilities. The ingenuity of farmers has been evident over the last 100 years, and I trust that there is a strong base of next generation farmers that will be the 'make it happen' people to confront these challenges.

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