Electrification of grain drying to reduce the impact of carbon pricing – preliminary investigation

Date: *March 2021*

Key Implications:

- *Heated air drying is an important strategy for corn production in Manitoba and for mitigating poor harvest weather conditions.*
- *Heated air drying with fossil fuel offers the versatility of drying almost any type of grain and is about the fastest method available.*
- *Drying in-bin with supplemental heat may be more energy efficient and may preserve higher grain quality; however, the drying time is longer.*
- *Careful management of grain drying is important to avoid costly reductions in grain quality*
- *A heat pump can be a way of improving on the strategy of using electricity to provide the thermal energy.*
- *Water absorbs RF energy rapidly and can dry grain without significantly heating the base material.*
- *A combination of technologies may offer the most efficient grain drying strategy.*

Challenge:

In recent years, driven by increased corn acres and more extreme climate patterns, grain drying has become a more prevalent on-farm management practice for managing harvest and storage risk. In Manitoba, drying is the third largest single production expense for corn after fertilizer and seed (Manitoba Agriculture and Resource Development, 2021). Fossil fuel is currently the primary thermal energy source for grain drying, resulting in a significant contribution to greenhouse gas emissions (GHGs). Generally, propane is used, as access to natural gas is limited.

The introduction of a carbon pricing has increased farm operating costs directly associated with drying. Manitoba generates almost 100% renewable electricity. Electrification of grain drying activities has been proposed as an alternative to fossil fuels and many innovative technology advancements suggest there are viable alternatives for farmers to reduce GHGs and avoid carbon pricing.

A preliminary feasibility study of equipment and the economic/environmental potential will be reviewed to identify if this is an area of investment worth considering for producers and industry. Both in-bin and heated air dryer (dedicated drying equipment) technologies are considered.

Conventional Grain Drying Methods:

Accelerated grain drying in Manitoba is primarily accomplished with heated air drying that uses fossil fuel to heat the air as high as 75°C using airflow rates up to 20 cfm/bushel. In Manitoba, dryers generally use propane for thermal energy and electricity for fan power and system grain flow. Heated air drying offers the versatility of drying almost any type of grain and is about the fastest method available. Management is required to avoid high temperatures that could damage the seed and cooling is required for storage. These are among the least energy-efficient methods of drying grain but remains popular as an economical way to reduce harvest delays. The risk of harvest delay is costly in terms of grain quality, and yield can be offset by a heated air dryer of suitable capacity.

Drying in-bin with supplemental heat uses electric fans along with a gas burner to increase air temperature to 15°C or 20°C at flow rates of 1 cfm/bushel. Inlet temperatures need to be managed to avoid overheating, and drying success comes with the eventual need to move the grain so that it can be mixed to achieve optimum and uniform results. This can be a more energy efficient method if managed carefully; however, the drying time is slower.

However, trade-offs do exist between these two approaches. In-bin supplemental heat systems require longer drying times but may not subject the grain to quality damage from high temperatures and additional handling. These systems also use less total energy per point of moisture removed. High-heat grain dryers do dry faster but at greater risk to kernel damage from elevated temperatures or rapid cooling.

In either case, careful drying management is important to avoid costly reductions in grain quality. Grain price is dependent on several factors that relate to grain drying. Average moisture content is the most obvious, and the key is to target optimization, as over drying or under drying results in reduced profits. In the case of heated air drying, optimizing the temperature to be near 75°C (depending on the grain type) achieves maximum capacity, but higher temperatures result in damaged kernels, lost nutritional value, and reduced germination viability from overheating (Distributed Energy Resources Work Group, 2020). Kernel damage results in a lower grade and reduced profits.

Electricity as Thermal Energy Source:

Grain dryer energy performance is measured as the energy consumed by the dryer to evaporate a mass of water from the grain (energy consumed/water evaporated). The energy consumed includes the thermal energy from the gas burner and the electric energy required to run the fans and grain flow systems. Electrical power in Manitoba is 100% from renewable sources so the carbon cost is basically that amount used to run the gas burner of the dryer.

Electricity can also be used directly as the thermal energy source for grain drying, which would eliminate the carbon cost. Even though the energy cost of electricity is competitive with the cost of propane in Manitoba, this method is not as popular. The reasons for this could include the higher cost of electrical heating equipment and the potential for additional electrical demand charges. High output heaters are better suited for three-phase power, but availability may be limited and comes with additional installation charges, especially for high-output equipment, which makes it a less economical option. For these reasons, electricity as a thermal source is of limited use and used almost exclusively with smaller, in-bin supplemental heating systems. Otherwise, fossil fuel systems are chosen for the greater economic feasibility of lower capital cost in spite of the environmental impact of carbon emissions.

A heat pump can be a way of improving on the strategy of using electricity to provide the thermal energy. This method uses electricity to pump heat from the ambient air into the grain bin drying system. A study of grain drying using air source heat pumps in Ontario revealed a coefficient of performance (COP) of 6.93 (Dyck, Dineen, Lubitz, & Epstein, 2018). A continuous-flow heat pump grain dryer under development in Europe uses the cold side of the heat exchanger to cool the grain in the final stages of drying.

Commercial installations of heat pump grain drying technologies are lacking and further studies in local conditions are needed to reveal the potential capacity. Otherwise, with all of the power supplied as electricity, this would be a carbon free way of drying grain in Manitoba.

Electrical Drying with RF and Microwave:

Grain drying using radio frequency (RF) and microwave energy (microwave) is based on the dielectric heating phenomenon of converting electromagnetic energy to heat. The terms RF and microwave are not clearly defined by specific frequencies but rather a general range. Microwaves describe a narrow portion of the electromagnetic spectrum within the broader category of radiofrequency. The frequencies used in grain drying are not necessarily within the microwave range. Microwave and RF heating both refer to the same dielectric heating phenomenon (Nelson, 1987).

RF drying involves directly heating materials at the molecular level. The base materials of a grain kernel are polymers that do not efficiently absorb RF energy, and as such, do not heat easily. Water on the other hand, absorbs RF very well so it heats rapidly. In this way, RF energy can drive the water from grain without significantly heating the base material of the grain kernel (Distributed Energy Resources Work Group, 2020). RF heating response changes with grain temperature so these must be balanced during operation to ensure the water is heated to the point that it can be driven out but not so much that it produces steam, which could lead to kernel damage.

A challenge to this technology on a larger scale is that the practical conversion of electrical power to RF or microwave power is theoretically about 50% (Nelson, 1987). However, this issue is possibly offset by the fact that the radio waves directly deliver energy to the water molecule. The physics of the heated air dryer is such that it actually heats the water in the kernel very indirectly. It uses hot air to heat the kernel from the outside, which in turn warms the water within the kernel causing it to migrate out of the kernel and evaporate into the air flow. Furthermore, this process needs to be done at a somewhat gradual rate to avoid overheating that can stress the damp kernel or rapidly dry the outer surface causing fissures or cracks (PCS a Litzler Company, 2020).

An RF grain dryer comparable to the capacity of conventional heated air grain dryers is not yet commercially available. However, at least one company, DryMAX Solutions, has a patent application for the "Systems and Methods of Drying Biomass using Radio Frequency Energy" and is actively developing methods for drying corn and other agricultural grains (Heine & Eichhorn, 2019). Prototype installations are operational with claims of efficiencies well beyond that of conventional dryers.

A broader understanding is needed to validate the claims and inform producers of the economic and environmental feasibility of this technology. There have been many lab-scale studies that show promising results. As for the future viability of this technology in Manitoba, additional installations are needed for unbiased third-party studies across a range of local conditions and crop varieties.

Potentially, RF drying is able to move the moisture from a single grain kernel with relative efficiency. However, there is still the matter of moving that moisture outside of the grain mass before it is simply reabsorbed by the kernel. Overcoming this might require a solution using RF drying in combination with heated air drying. The combination of two technologies, using the RF heating to drive moisture from inside the kernel to its surface, and then conventional methods such as fan forced air with supplemental heat for moisture removal from the grain mass, may offer the most efficient strategy (PCS a Litzler Company, 2020).

Biomass Drying Systems:

There are also certain biomass-fueled drying systems available or in development that claim to be more efficient than traditional fossil-fuel driven dryers. Biomass, such as wood chips and crop residue, are used to fuel the heat source rather than propane or natural gas, which are known to consist of high percentages of water (Triple Green Products, n.d.). Biomass drying systems may be a viable alternative for producers, but require further investigation to determine market availability and efficiencies.

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Summary:

Conventional grain dryers rely heavily on fossil fuel to provide thermal energy for drying. This raises concern for the environmental impact of carbon emissions. Manitoba generates almost 100% renewable electricity, so finding a way to dry grain with electricity would provide an alternative for farmers to reduce greenhouse gas emissions and avoid carbon pricing payments. Advancements that demonstrate potential as carbon-friendly solutions include dryers powered by thermal electric heat, electric heat pumps, RF drying, and biomass (although further investigation is required into these systems). A combination of these technologies may offer the best way toward to an efficient strategy. Given that these technologies rely entirely on electricity, the opportunity to offset carbon compares favorably in the province of Manitoba.

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