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CURRENT TECHNOLOGY AND ENERGY EFFICIENCY OPPORTUNTITIES FOR ALBERTA COMMERCIAL BEEKEEPING INDUSTRY

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PREPARED FOR:
ALBERTA BEEKEEPERS COMMISSION

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1. Executive Summary

The purpose of this report is to describe the current technologies and energy consumption of the Alberta commercial beekeeping industry and also to identify opportunities for energy efficiency improvements to increase sustainability and reduce the carbon footprint of commercial beekeeper farm operations in Alberta.

Nine beekeeper facilities were selected as a sample set of farms to represent the industry in Alberta. The sample farms were visited to:

1. measure energy consumption of different equipment.
2. identify the most energy efficient equipment and practices among those producers.
3. make farm-specific recommendations for energy efficiency improvements.

Our site visits showed that it is economical to implement energy-efficiency improvements to reduce energy consumption at the sample farms ($/hive) by an average of 5.1% for diesel & gasoline, 2.7% for propane, 29.5% for electricity, and 1.4% for natural gas.

The estimated costs to implement energy efficiency improvement opportunities for the sample farms included the application of rebates, for certain qualifying upgrades, available from FEAP (Farm Energy Agri-Processing Program) [1].

The economics of energy efficiency opportunities, averaged by equipment category, recommended to the sample farms had payback periods ranging from 2 years to 9 years, and internal rate of return on investment (IRR) in the range of 7% to 182% over the economic life of the implemented improvement.

The recommended energy improvements at the sample farms are expected to reduce the average annual farm energy costs from $11.566/hive to $10.839/hive, which is an energy-cost savings of 6.3% or $0.727/hive. The average sample farm size was 5365 hives/farm with an average energy-cost savings potential of $3,900/year. The average energy savings by energy source would be $1029/year (0.192/hive), natural gas $11/year ($0.002/hive), propane $35/year ($0.007/hive), and diesel & gasoline $2825/year ($0.527/hive).

Based on a 2017 survey there were 1420 beekeepers in AB [2], with 317,000 colonies. To extrapolate the sample farm findings to the rest of the AB commercial beekeeping industry, we could assume that 90% of hives in the province (285,300 hives) are owned by 256 commercial beekeepers (18% of AB commercial sized over 300 hives [3]) with an average of 1114 hives/farm. If those 256 commercial beekeepers have a similar energy efficiency improvement potential as the sample farms, the energy-cost savings would translate to an industry total of $207,413 per year.

Based on emissions intensity factors [4] of different energy sources in AB, the emissions of GHG (greenhouse gases) associated with the commercial beekeeping industry (estimated 256 farms and 285,300 hives) in Alberta is 8789 tCO2e/year (carbon dioxide equivalent of multiple greenhouse gases, measured in tonnes). The potential for energy efficiency upgrades across the province could reduce GHG emissions for the commercial beekeeping industry by 8.1% or 709 tCO2e/year.

2. Introduction

The Alberta Beekeepers Commission, with support from the Canadian Agricultural Partnership, has engaged Dandelion Renewables to conduct a project to research and also identify opportunities for energy efficiency improvements for farms to save on energy costs, increase sustainability, and reduce the carbon footprint of commercial beekeeper farm operations in Alberta. The project includes research about current technologies and energy consumption of the commercial beekeeping facilities, the evaluation of opportunities to integrate renewable energy technologies with beekeeping facilities including a conceptual design of a net-zero overwintering facility (A "net-zero" facility generates as much renewable energy as it consumes from any energy sources, on an annual basis). The integration of renewable energy technologies and the net-zero design of an indoor overwintering facility will be addressed in a separate report.

Nine commercial beekeeping farms were visited to represent a set of "sample farms" in the AB commercial beekeeping industry. Dandelion Renewables visited the sample farms during the first half of 2019. The farm sizes ranged from 2500 hives to 10,000 hives, with the average size of the sample farms at 5365 hives. Each farm was provided with a farm-specific report with recommendations for the most cost-effective opportunities available for the farm to improve energy efficiency, reduce energy costs, and to reduced greenhouse gas emissions associated with the energy consumption of the farming operations.

The following sections of this report summarize the current technologies being used in the commercial beekeeping industry in Alberta, the recommendations applicable to the sample farms, and the opportunities identified for potential energy efficiency improvements at other commercial beekeepers in Alberta.

3. Current Energy Costs and Cost-Saving Opportunities

All nine of the sample farms visited were using electricity, propane, diesel and gasoline. Eight of the nine farms were also using natural gas.

The energy costs referred to in this report are the "variable" portion of energy costs that can be directly reduced by reducing energy consumption. This excludes the "fixed" portion of energy costs, such as the flat-rate monthly administrative fee on most electricity bills.

Current Energy Costs

The average annual farm-energy cost was found to be $11.566/hive, which comes from different energy sources including diesel & gasoline ($10.303/hive), electricity ($0.669/hive), natural gas ($0.372/hive), and propane ($0.263/hive).

The following figure shows the breakdown of the average annual farm energy costs ($/hive) by energy source.

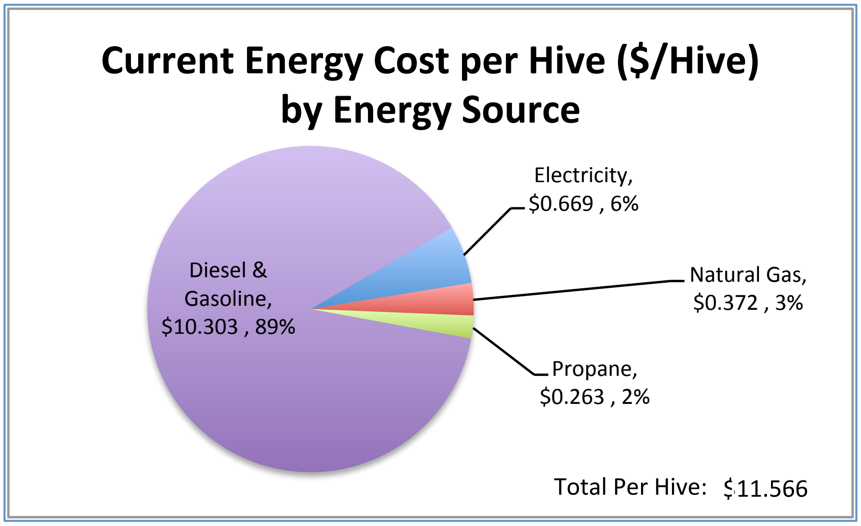

Figure 1: Average energy cost by energy source at sample farms. Costs are shown as $ per hive. Percentages are shown as % of total farm energy cost.

The average energy costs were attributed to different equipment categories or systems, which are shown in the following figure. The averages include "applicable farms" only, ignoring farms that don't use that type of equipment (e.g. not all farms had wax melters, heat trace, dehumidifiers, or indoor overwintering rooms).

Vehicles (primarily diesel fuel costs) contribute 88% of the total farm energy cost.

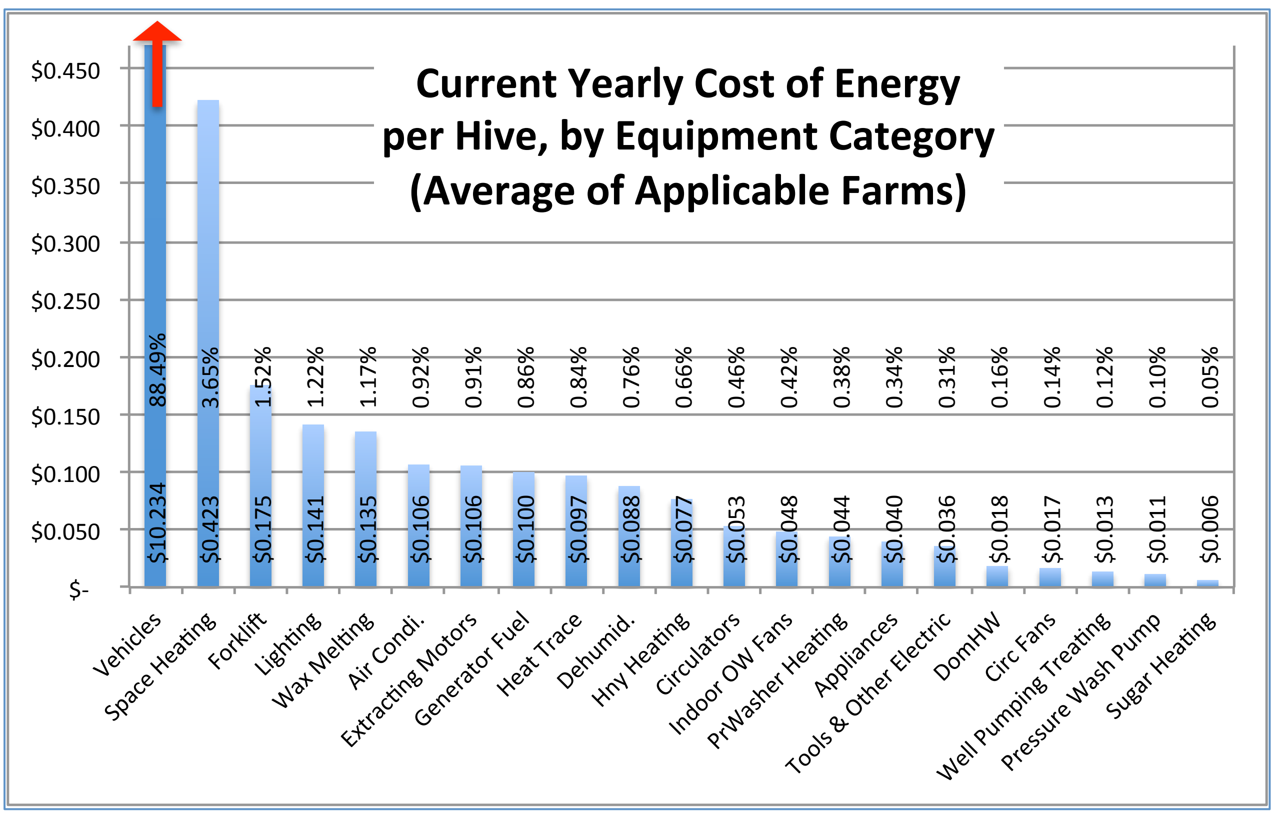

Figure 2: Average energy cost distribution by equipment category at applicable sample farms. Costs are shown as $ per hive. Percentages are shown as % of total farm energy cost.

Energy-Efficiency Improvement Opportunities

Technologies with opportunities at the applicable sample farms to reduce energy consumption and costs have been identified in the following order of highest to lowest potential for annual cost savings per hive:

1. Vehicles
2. Heat Trace
3. Wax Melting
4. Space Heating
5. Honey Heating
6. Lighting
7. Indoor Overwintering Fans
8. Pressure Washer Heating
9. Appliances
10. Circulators

The following figure shows the expected energy savings by equipment category, based on the applicable sample farms. "Applicable" sample farms in the figure include only the farms where an energy efficiency improvement opportunity was identified as economical (positive IRR).

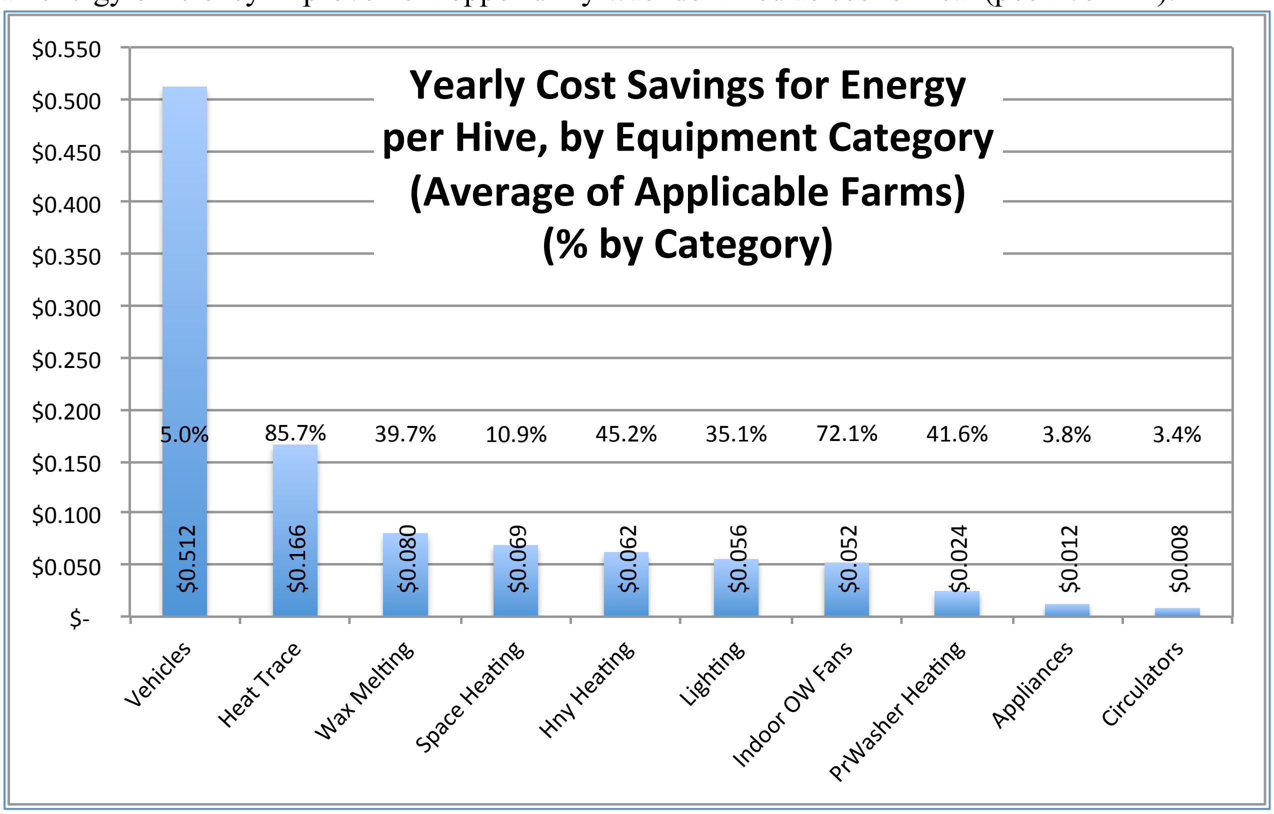

Figure 3: Average energy savings by equipment category at applicable sample farms. Cost savings are shown as $ per hive, and percentages are shown as % of costs for each individual category.

The economics of investments in energy efficiency upgrades at the sample farms were calculated and prioritized by equipment category in the following order from lowest to highest payback periods:

1. Vehicles
2. Heat Trace
3. Wax Melting
4. Space Heating
5. Honey Heating
6. Lighting
7. Indoor Overwintering Fans
8. Pressure Washer Heating
9. Appliances
10. Circulators

The following figure shows a summary of the economics for the energy cost savings opportunities identified at applicable sample farms. The payback period (years) refers to how long it will take for the expected cost savings to equal the initial investment cost of project implementation. The IRR is the internal rate of return on investment, over the economic life of the improvement project.

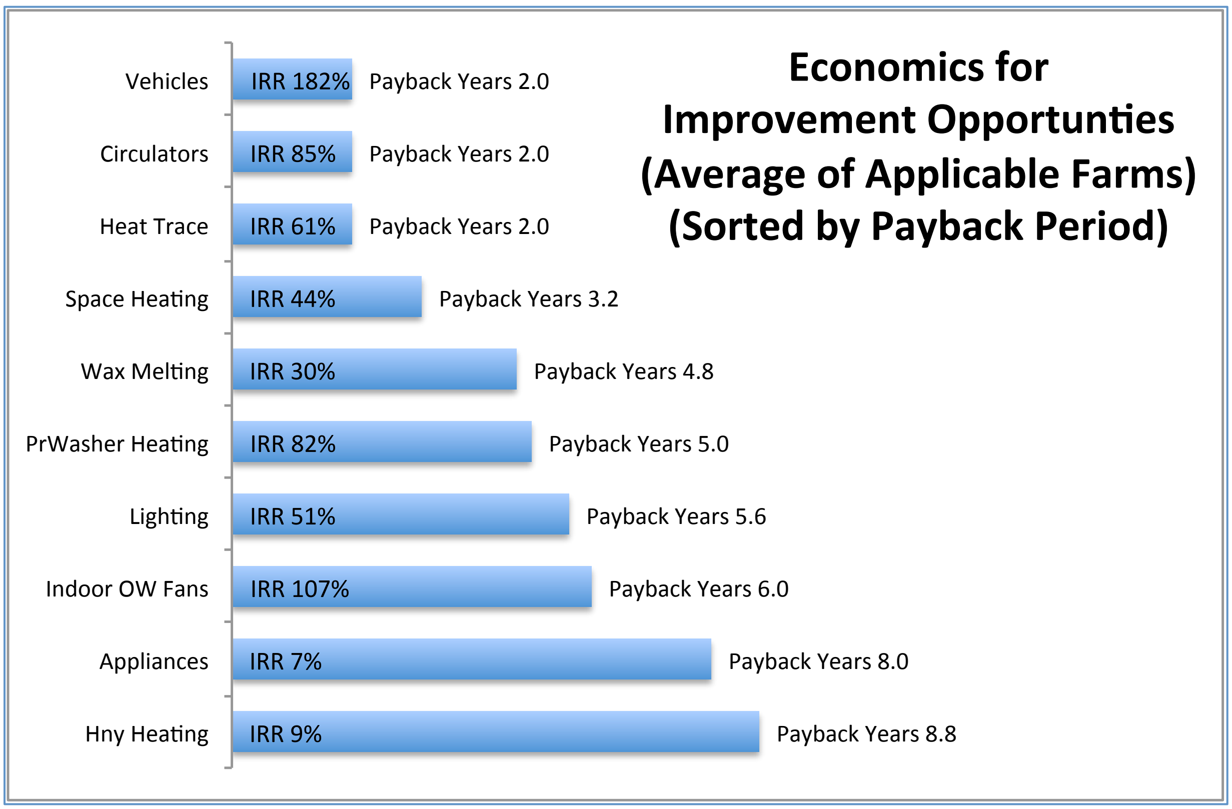

Figure 4: Average economics of energy efficiency upgrade opportunities by equipment category at applicable sample farms.

The following figure shows a summary of the potential energy cost savings at sample farms extrapolated to the rest of the commercial beekeeping farms across Alberta.

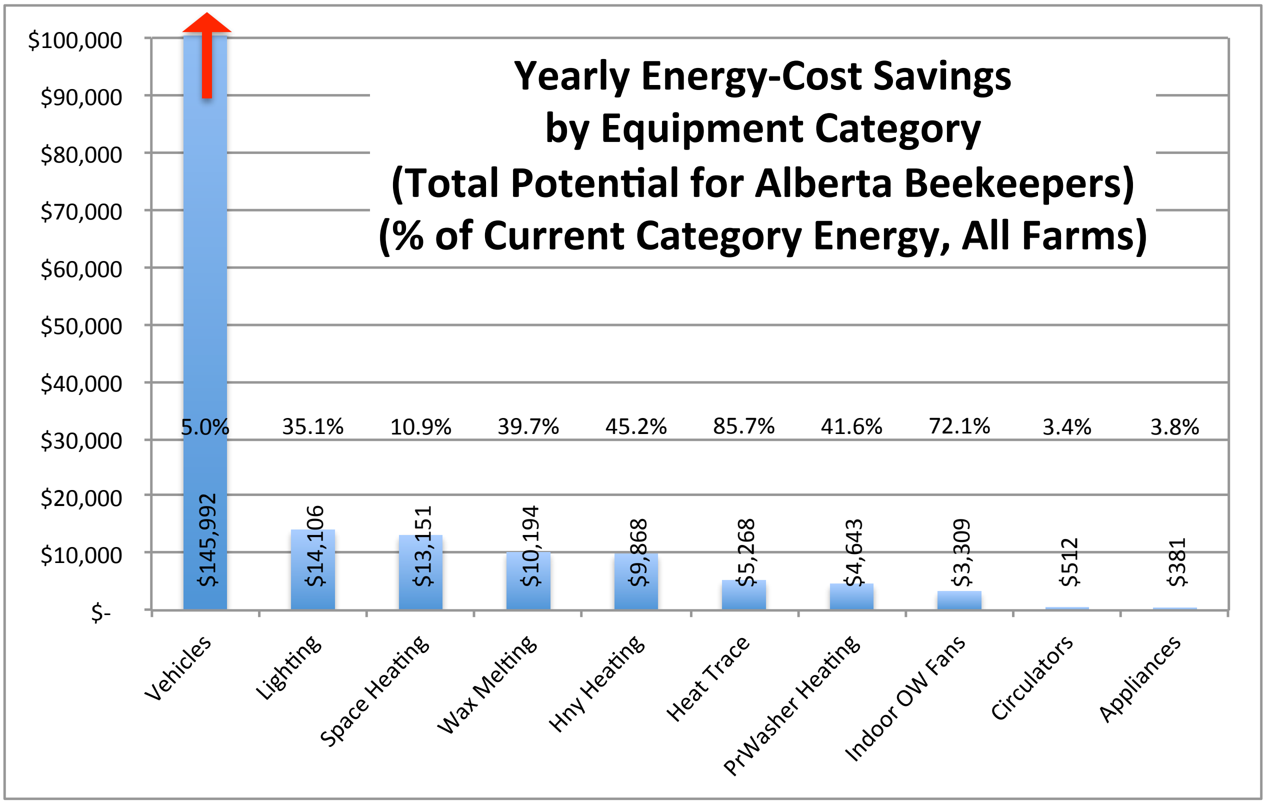

Figure 5: Total energy-cost savings of potential energy efficiency upgrades for all commercial beekeepers in Alberta. Based on estimate of 256 commercial beekeepers and average 1114 hives per farm.

4. Current Technology and Energy-Efficiency Improvement Opportunities

4.1. Vehicles

<u>Current Types of Vehicles at Sample Farms:</u>

All of the sample farms were using a combination of flat-deck diesel trucks varying in deck sizes and loading capacities, to transport hives, other equipment, and crew between the farm site and the apiaries (hive sites). The maximum distances between the sample farms and their farthest hive sites varied from 27km to 250km. Due to these differences in distances, the size and seating capacity of trucks at different farms varies.

Figure 6: Example of a Diesel Flat-Deck Truck (2016, F550, Dually, 4x4, Crew-Cab, 12ft)

One of the most common sizes of diesel trucks observed at sample farms was a 6-seater, crew cab, 4x4, dually, 12-foot flat-deck truck, with 5742kg payload capacity (see the example figure to the right). This truck size gets used throughout the year to transport crew and hives to apiaries for hive maintenance and manipulations.

Figure 7: Example of a Diesel Flat-Deck Truck (2000 Intl 8100, Tandem, 4x6, 24ft)

The other most common size of trucks observed at sample farms was a 2-seater, tandem, 6x4 (2 rear drive axles), 24-

foot flat deck-truck, with 18,000kg payload capacity (see the example figure to the right). This truck size gets used most for transporting honey supers during the honey harvest months.

Vehicle Fuel Efficiency Improvement:

Light duty and medium duty trucks typically do not have fuel efficiency ratings. This is due to the wide range of truck configurations (e.g. flatbed, enclosed box, dump body) as well as the variation of truck loading.

The sample farms were not tracking the fuel consumption by trip or by truck, but two of the farms did report some experiences where they had noted in the past that fuel efficiency of different trucks in their fleet used significantly more or less fuel than others.

There is an opportunity for farms to improve fuel economy for their existing trucks by doing two things:

1. Farms can log fuel economy by truck for each fuel fill-up, the amount of fuel added to the tank, the distance travelled on that tank of fuel, the type of driving or loading, and who was driving. This log will allow the farm to compare fuel economy for repetitive trips with the same truck and also to compare different trucks.
2. Farms can provide driver training to encourage driving habits that achieve better fuel efficiency, which could include: avoid high speeds, accelerate gently, coast to decelerate, maintain steady speeds, anticipate traffic ahead to avoid hard braking or rapid acceleration.

The driver training and fuel monitoring investment is expected to save at least 5% of diesel consumption for the farm. This estimate is conservative relative to the suggested impact of up to 25% savings published on the Natural Resources Canada website [5].

Vehicle fuel costs at the sample farms was on average $10.234/hive per year. Based on 285,300 commercial farm hives in AB, this cost is $54,905 per year for a farm. A 5% annual reduction in fuel consumption through improved fuel economy could save $2745/year. The payback for the farm is expected in the first year after implementing the driver training and fuel economy monitoring.

The average vehicle fuel costs at sample farms was $10.234/hive per year. The average savings from recommended improvements was 5.0% ($0.512/hive). The recommended improvements for vehicle fuel savings had an average payback period of 2 years, and 182% IRR.

Based on an estimate of 256 commercial beekeepers in Alberta with an average farm size of 1114 hives, and 100% of the farms achieving an average vehicle fuel savings of $0.512/hive, this could have a total savings for the Alberta beekeeping industry of $145,992/year.

Renewable Diesel for Existing Diesel Trucks to Reduce GHG Emissions:

None of the sample farms were using renewable diesel beyond the conventional concentrations of renewable diesel that are pre-blended with petroleum diesel sold at fuel retailers throughout Alberta.

What is renewable diesel?
"Renewable diesel" refers to any diesel fuel made from renewable sources, such as vegetable oils or animal oils or fatty acids. [1] The two main categories of renewable diesel are generally referred to as "hydrogenation derived renewable diesel" (HDRD) and "biodiesel". The main differences between HDRD and biodiesel are in the way they're made and in the way they perform at colder temperatures (e.g. between -43C and 0C). "Biodiesel" is a term typically used to refer to a certain group of renewable diesels that are made using a process that combines renewable feedstock (e.g. vegetable oil) with a catalyst (e.g. Lye) and an alcohol (e.g. methanol or ethanol). Another name for biodiesel is FAME (fatty acid methyl esters). HDRD is also made using renewable feedstock, but uses the same refining processes as petroleum diesel fuel.

The largest biodiesel producer in Canada is ADM located in Lloydminster, AB. That biodiesel uses canola as feedstock, with a biodiesel production capacity of 265 million liters per year [7].

How can farms reduce diesel costs by substituting more renewable diesel (e.g. B100)?
There is an opportunity to reduce diesel costs in the summer by using Biodiesel B100 at a lower cost than petroleum diesel, although the opportunity requires unique fuel delivery planning with a group of farms, and pursuit of environmental program funding based on the reduced greenhouse gas emissions from biodiesel versus petroleum diesel.

The two main price factors that can make biodiesel cheaper to use than petroleum diesel are government environmental incentives in favor of biodiesel, and lower-cost feedstock supplies for making the biodiesel. The US government applies incentives for biodiesel, which has translated to cheaper biodiesel costs at the pumps than regular diesel (based on a phone call to a US biodiesel retailer, the regular diesel B5 was $3.19/gal, B20 was $2.89/gal, B100 was $2.99/gal). There is an opportunity for the farming industry to influence government programs to incentivize biodiesel use and potentially to obtain funding through current programs based on reduced greenhouse gas emissions of using more biodiesel and less petroleum diesel.

The use of biodiesel can reduce GHG emissions by over 80% compared to petroleum diesel, on a lifecycle basis, according to Natural Resources Canada. In addition to the benefit for the atmosphere, biodiesel can significantly reduce human health risks associated with petroleum diesel exhaust [7].

B100 is not currently available at retail fueling stations (e.g. UFA, Shell, Esso), but it is available in fuel tanker order sizes (e.g. up to 63,000L super-B tanker truck) directly from the biodiesel producer. The cost of the biodiesel can be lower than petroleum diesel as bulk purchases, but the transportation and storage of the higher concentration biodiesel requires special arrangements to keep the delivery economical, since an on-farm bulk fuel tank typically has a capacity closer to 3000L.

What about cold weather performance and engine maintenance?
The Renewable Fuels Standard regulation in Alberta (and federal regulation) already requires that all diesel fuel sold in Canada must contain at least 2% concentration of renewable diesel. [2]

Biodiesel (B100) requires more modification and care for cold-weather handling than petroleum diesel, where biodiesel fuel gelling or fuel separation has been observed at or below 0C compared to conventional summer petroleum diesel at or below -16C. HDRD cold-weather handling is comparable to conventional petroleum diesel with HDRD fuel gelling or separation observed at or below -19C. In Alberta, the diesel fuel separation temperatures for petroleum diesel and for renewable diesel are adjusted lower (e.g. as low as -43C) by blending with kerosene during colder months of the year. [1]

Is renewable diesel compatible with existing diesel engines?
Generally, any petroleum diesel engine will run a blended diesel, up to 20% concentration of renewable diesel mixed with petroleum diesel, without any noticeable impact on performance or maintenance. However, the use of biodiesel concentrations above B5 (5%) in newer vehicles still under warranty should be checked with manufacturer warranty compatibility. To use renewable diesels (biodiesel or HDRD) at concentrations above 20%, such as 100% renewable diesel, most diesel engines are already expected to be fully compatible. However, biodiesel (e.g. FAME) has a mild-solvent characteristic which can compromise older fuel seal materials such as Buna or Nitrile that have been found on vehicle engines manufactured before 1994. The modern standard for fuel seal materials (e.g. Viton) are solvent-resistant and compatible with biodiesel fuels. [2] [3]

Where can AB farms get a higher concentration of renewable diesel?
Biodiesel, although made in Alberta, is only available to retail customers (at the pump) in a 5% blended (B5) concentration with petroleum diesel. Higher concentrations of biodiesel are not readily available for purchase in Alberta, at small fuel delivery volumes that individual farms store onsite in farm-owned diesel bulk tanks. The majority of Canadian-made biodiesel gets exported to the USA. Canada does however import more renewable diesel than it exports [12]. One explanation for this is the seasonality of canola oil feedstock produced in Canada, as well as the incentives paid by the US government available to biodiesel producers.

Hybrid-Electric Diesel Trucks and Electric Trucks:

Hybrid-electric vehicles (HEV) and battery electric vehicles (BEV) use batteries and electric motors to improve fuel efficiency and reduce the cost of operating the vehicle versus internal combustion engines (ICE) such as diesel engines.

There is an opportunity for farms that are looking to buy a newer diesel vehicle to consider upgrading to a hybrid-electric-diesel instead of the diesel-only version, with a positive return on the extra investment cost of the hybrid version. The options to buy hybrid-electric light-duty trucks in Canada are still limited but they are starting to become available. In the years to come, battery-electric vehicles may become available without internal combustion engines that beekeepers can begin to adopt in their fleet for further diesel fuel savings.

What is an electric vehicle and when is it cheaper than diesel or gasoline?
Electric vehicles have electric motors to propel the vehicle instead of a diesel or gasoline internal combustion engine. Electric vehicles require more energy to manufacture but they use less emissions and cost less to operate than internal combustion vehicles over the life of the vehicle [13]. The economics of electric vehicles continues to become more attractive as the costs of

manufacturing batteries continue to drop and governments are incentivizing the development and adoption of electric vehicles (e.g. Canada charging infrastructure [13] as well as the iZEV vehicle rebates program [13]). Amazon ordered 100,000 electric delivery vans in 2019, and electric semi-trucks have been ordered by Walmart, UPS, and PepsiCo [16].

What is a hybrid-electric vehicle?
Hybrid-electric vehicles use both an internal combustion engine and electric motors with batteries to improve fuel efficiency. The electric motors can be used to more efficiently accelerate the vehicle as well as slow the vehicle down by charging the batteries (referred to as regenerative braking).

Are hybrid-electric light-duty trucks available and economical in Alberta?
Hybrid-electric diesel light-duty trucks are starting to be available in Canada, such as the Hino Hybrid 195H with a payload around 4500kg. The price premium to buy this truck as a hybrid-electric-diesel instead of the diesel-only version is around 19.5% ($79,650 vs $66,650 CAD). If we assume a 15-year life of the vehicles, 30,000km per year, with the same maintenance costs, and 25L/100km for the diesel version and 19L/100km for the hybrid-electric version (24% improved fuel economy), and an average diesel cost of $1.05/L, the hybrid-electric would save $28,350 of diesel fuel cost over the life of the vehicle. The savings would be $1890/year, which is a simple payback of 7 years for the premium cost of $13,000 to buy the hybrid-electric instead of the diesel.

The Hino 195H is only available as 2-wheel-drive, and it doesn't currently allow the truck to move without the diesel motor running, so it may not be suited to the requirements of most beekeepers (e.g. 4x4 is typically required). However, the availability of this truck in Canada is an indication that electric vehicle technology is entering the Canadian light-duty truck market. If electric vehicle and battery developments continue to progress as industry experts forecast, it is only a matter of time until the operating economics shift from diesel trucks to electric trucks for a wider range of truck classes and configurations [17].

4.2. Heat Trace

<u>Electric-Heated Cables as Heat Trace on Water Lines:</u>

Heat trace refers to adding a source of heat along a path, most commonly to prevent a waterline (pipe) or water trough from freezing.

22% of the sample farms (two out of nine) visited were using thermostat-controlled electric-heated cables wrapped onto waterlines to prevent freezing through winter months. One of the waterlines was above ground, due to farm expansions requiring more water than the existing buried waterlines could provide. Another farm had a buried waterline that was not deep enough to get below the frost depth of the ground. To prevent the waterlines from freezing, without using electricity, waterlines can be buried deep enough in the ground to be below the frost depth for that region.

Unearthing an existing waterline and burying it deeper can be expensive, relative to the energy cost of operating heat trace in some applications, so the consumption of energy of the heat trace should be considered when deciding whether to move an existing buried waterline.

The average annual heat trace energy cost at applicable farms (those operating heat trace) was $0.097/hive. The average savings from recommended improvements was an 85.7% reduction of heat trace energy costs or $0.018/hive. The recommended improvements for heat trace had an average payback period of 2 years, and 61% IRR.

Based on an estimate of 256 commercial beekeepers in Alberta with an average farm size of 1114 hives, with an average heat trace savings of $0.018/hive, this could have a total savings for the Alberta beekeeping industry of $5268/year.

4.3. Wax Melting

Types of Wax Melters

67% of the sample farms were using wax melters to render wax blocks from the wax caps. Wax caps (cappings) get trimmed from the honeycomb as part of the honey extraction process. The other 33% of farms were paying for outsourced wax rendering.

Wax melting equipment is used to heat the wax above its melting point temperature of 64C causing the wax to separate from other things in the tank such as water, debris, slum-gum, and residual honey. The wax can then be poured into a mold and cooled to make a stackable wax block.

The most common type of wax melter at sample farms was the single barrel tank type, with a 1500W electric heating element that heats a water jacket around the tank.

One of the sample farms was using a larger capacity multi-barrel custom-made wax-melting tank, which used a natural gas boiler to heat a water jacket. The purpose for the larger tank was to reduce the labour time required to melt wax by increasing the batch size and reducing the number of fills and poor-offs required each year.

One of the sample farms was using a continuous flow wax melter (made by Cook & Beals). The wax melter uses electric elements to heat a water jacket (or vegetable oil jacket) that heats the wax through the tank surface.

Wax Melter Heating with Natural Gas Boiler to Reduce Electric-Heating Costs

There is an opportunity to retrofit the water jacket of existing electric-heated wax melter tanks to also be heated from an existing natural gas boiler at the farm. The boiler water can be used to go through a heat exchanger to heat the water jacket, or the jacket can be sealed to accept boiler water circulation and pressure directly. Due to boiler output temperatures typically below 60C (140F), the boiler temperature isn't able to heat the wax effectively past the melting point temperature, but the boiler can be used to provide most of the wax-heating requirement (e.g. from

25C to 50C). The electric heating elements are still required for final heating of the wax above the melting temperature.

The average energy cost of wax melting at the applicable sample farms was $0.135/hive. Based on recommended improvements for sample farms to retrofit existing electric wax melting tanks with heating from existing natural gas boilers, the average energy cost savings estimated for the sample farms was 39.7% ($0.036/hive). The recommended improvements for wax melter upgrades had an average payback period of 4.8 years, and 30% IRR.

Based on an estimate of 256 commercial beekeepers in Alberta with an average farm size of 1114 hives, with an average wax melter energy cost savings of $0.036/hive, this could have a total savings for the Alberta beekeeping industry of $10,194/year.

4.4. Pressure Washer Heating

56% of the sample farms had a diesel-fired pressure washer that heats the cold supply water with a diesel burner, and uses an electric pump (corded) to provide the water pressure to the spray nozzle. The thermal efficiency of the diesel burner in the pressure washer is estimated at 60%. This means that 40% of the heat energy from the diesel burner is lost in the exhaust gases.

All of the sample farms had a domestic hot water tank (or on-demand heater, or indirect-fired tank from a boiler) that is heated by natural gas (or propane). Natural gas is a lower cost heat energy source than diesel, and the natural gas water heating equipment at the sample farms had a higher efficiency than the diesel burner.

There is an opportunity for farms to add a domestic hot water line to supply the pressure washer with pre-heated water, to reduce the diesel burner heating load to just a top-up of the water temperature, as needed for pressure washing.

A thermostatic mixing valve (anti-scald valve) would be required so that the domestic hot water sent to the pressure washer is no hotter than 120degF (49degC). If domestic hot water were fed directly to the pressure washer at 140degF (60degC) or higher, the pressure washer pump-head could be damaged as it is not designed to withstand that high temperature of water. It is also important for operators to ensure that the pump isn't left sitting in bypass mode (non-spraying recirculating mode) for more than a minute or two, because the pump can overheat itself.

The economics for this upgrade included an estimated efficiency of 75% for the domestic hot water (including heater efficiency and heat losses in the hot water hose to the pressure washer), and 65% of the pressure wash-water heat supplied by the domestic hot water heater (35% of heat topped up by the pressure washer heater).

The average cost of pressure washer heating at the applicable sample farms was $0.044/hive. Based on recommended improvements for sample farms to add domestic hot water supply lines to pressure washers, the average energy cost savings estimated for the sample farms was 41.6% ($0.016/hive). The recommended improvements had an average payback period of 5.0 years, and 82% IRR.

Based on an estimate of 256 commercial beekeepers in Alberta with an average farm size of 1114 hives, with an average energy cost savings of $0.016/hive, this could save the Alberta beekeeping industry a total of $4643/year.

4.5. Appliances

Clothes Dryers -- Electric-Heated versus Natural Gas

89% of the sample farms were using electric-heated clothes dryers for workers coveralls or suits.

There is an opportunity for certain farms to replace the electric-heated clothes dryer to a natural gas heated clothes dryer, with a positive return on investment. The economics of the upgrade assume only an incremental cost of buying a natural gas dryer instead of an electric dryer, and not a replacement of a functional electric dryer. This means that the upgrade to the natural gas dryer is done at a time when the farm is installing a new dryer anyway, such as replacement of an existing dryer at the end of its useful life.

For this opportunity to be economical, the cost of piping natural gas to the appliance location must be very reasonable, such as an existing natural gas line in the same room already, which can be tied into the appliance with a relatively simple and short run of pipe.

The average energy cost of appliances at applicable sample farms (primarily clothes dryers) was $0.040/hive. Based on recommended improvements for sample farms to switch to natural gas clothes dryers, the average energy cost savings estimated for the sample farms was 3.8% ($0.001/hive). The recommended improvements had an average payback period of 8.0 years, and 7% IRR.

Based on an estimate of 256 commercial beekeepers in Alberta with an average farm size of 1114 hives, with an average energy cost savings of $0.001/hive, this could save the Alberta beekeeping industry a total of $381/year.

4.6. Indoor and Outdoor Overwintering

Overwintering bees is the process of providing bees with a level of protection from the winter weather to make it easier for them to survive and maintain better health through to spring.

100% of the farms visited were overwintering at least half of their beehives outdoors. Outdoor overwintering involves placing tarps on the hives to provide added shelter from the cold and wind.

Three of the nine sample farms were operating indoor overwintering rooms for a portion of their beehives (24% of hives on average). The farms reported the main benefit of indoor overwintering

Three of the nine sample farms were operating indoor overwintering rooms for a portion of their beehives (24% of hives on average). The farms reported the main benefit of indoor overwintering versus outdoor overwintering was the ability to reduce winter losses. Winter losses refer to the percentage of hives that don't survive through the winter. The farms estimated between 5% and 15% reduced overwintering losses for the hives wintered indoors, versus the estimated losses those hives would have experienced if they were overwintered outdoors in the particular field locations from which they were removed. The hives selected for indoor overwintering are typically selected from outdoor areas that the farms have experienced poor outdoor overwintering results. This selection process allows the farms to maximize the hive survival improvements by indoor overwintering the selected hives.

The energy consumption of the indoor overwintering room climate control system consists of electricity to run climate-monitoring equipment and exhaust fans that move air out of the overwintering room that gets replaced by fresh air. The farms reported that no heating cost was needed for the indoor overwintering rooms, as the bees generate sufficient heat to prevent the room from getting too cold.

4.7. Indoor Overwintering Room Climate Control

Three of the nine sample farms were observed with indoor overwintering rooms. One of those farms had only variable speed fans, another farm had all single speed fans, and one farm had a combination of variable speed and single speed fans.

There is an opportunity for farms using variable speed fans in indoor overwintering rooms running most of the hours of the overwintering months to upgrade the fan controls and fans to ECM fans (described in the following section). The farms can also upgrade the climate control system to monitor outdoor temperature so that the fans won't run to cool the room if the available air outside the room is warmer than inside the room.

The average energy cost of indoor overwintering rooms at applicable sample farms (primarily ventilation fans) was $0.048/hive. Based on recommended improvements for sample farms to switch upgrade fans and controls, the average energy cost savings estimated for the sample farms was 72.1% ($0.012/hive). The recommended improvements had an average payback period of 6.0 years, and 107% IRR.

Based on an estimate of 256 commercial beekeepers in Alberta with an average farm size of 1114 hives, with an average energy cost savings of $0.012/hive, this could save the Alberta beekeeping industry a total of $3309/year.

<u>Exhaust Fan Motor Efficiency and Fan Controls:</u>

Exhaust fans remove air from the indoor overwintering room to maintain air quality. Exhaust fans at sample farms were either located through the wall or through the ceiling as a chimney. Exhaust fans create negative static pressure in the room, which draws fresh air into the room through air inlets.

Fan diameter has a large impact on fan efficiency in terms of the power consumed per volume of air moved (watts per cfm). For example, a 17" Multifan uses 73% more power than a 51" fan to move the same volume of air (3-blade wall fan, fiberglass cone, www.multifan.com).

Exhaust fans are controlled by a programmable ventilation controller, which can typically turn fans on or off or adjust the speed of variable speed fans.

For variable speed fans and fan control technology, there are three main types:

1. The most common variable speed control found at the sample farms was a single-phase fan controlled with a triac. The triac is one of the least efficient variable speed controller technologies but it is also one of the least expensive to buy. The triac adjusts the voltage supplied from the control to the fan but does so by chopping the AC waveform. Inefficiency comes from the resulting vibration and heat in the motor. The advantage of a triac control is the lower initial cost and simple wiring. The life of the fan motors used with triac controls is typically shorter than when using other variable speed motor control technologies.
2. Variable frequency drives (VFDs) are powered by single-phase or three-phase power and modify the frequency of the AC power supplied to the fans (typically used with a 3-phase fan motor). The change in frequency changes the speed of the fan. VFD technology is more efficient than triac at lower speeds, although the VFD is less efficient at full speed than the triac (see the following figure).
3. Electronically commutated motor fans (ECM fans) use single-phase or three-phase AC power. Electronics at the fan invert the AC to DC power and drive a DC brushless fan motor using pulse width modulation. ECM fans are more efficient than VFD or triac technology at any fan speeds (see the following figure).

Variable speed exhaust fans using VFD and ECM technology require a 0-10VDC modulated signal from the controller to set the speed of the fan. Existing controllers at sample farms that use a triac for the variable speed fans did not have a 0-10VDC available to control a VFD or ECM fan, in which case the controller would need to be replaced or upgraded to provide the 0-10VDC output. Controllers with 0-10VDC outputs for fans are available in certain models from most controller manufacturers.

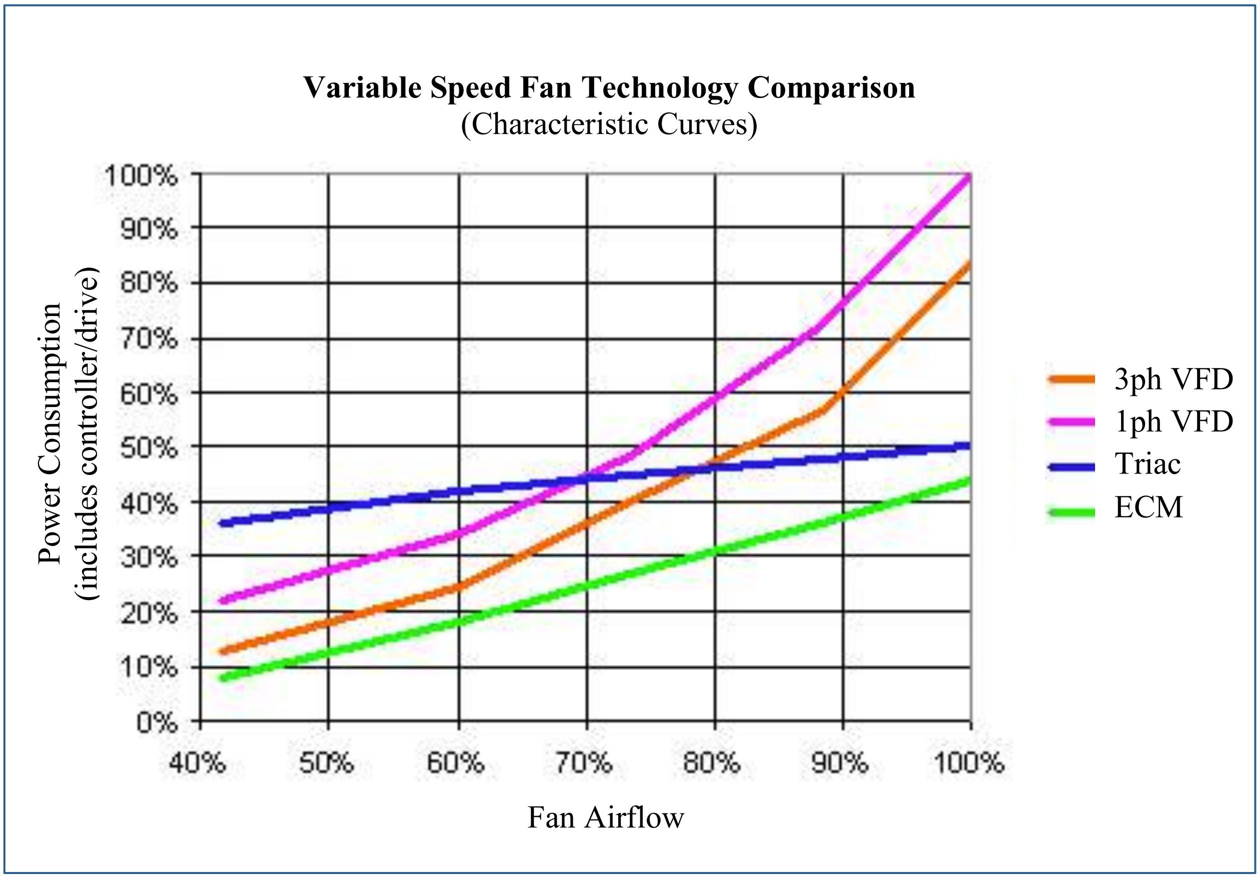

Figure 8: Variable Speed Fan Technology Comparison (study data from Control Resources Inc.)

The figure above shows that at a high-airflow fan speed:

- three-phase VFD uses 89% more power than ECM.
- single-phase VFD uses 127% more power than ECM.
- triac uses 14% more power than ECM.

The figure above shows that at low-airflow fan speed:

- three-phase VFD uses 63% more power than ECM.
- single-phase VFD uses 175% more power than ECM.
- triac uses 350% more power than ECM.

4.8. Space Heating

Natural Gas Boilers for Space Heating and Process Heating:

The most common space heating energy source observed in commercial beekeeper buildings were natural gas boilers. Boilers use natural gas to heat water, and circulators move the hot water through the building in pipes where the heat is exchanged into areas through in-floor pipes, or water fan-coil radiators, or other types of heat exchangers. Smaller loops of pipe called zones use zone-valves and/or zone-circulators to supply heat to rooms, controlled by a thermostat or climate controller.

Most farms had condensing high-efficiency boilers with a rated efficiency of 90-96%. The efficiency rating of 90% means 10% of the heat from the natural gas combustion is expected to be lost as heat through the combustion exhaust. The condensing aspect of the boiler means that more heat is removed from the combustion exhaust by removing so much heat from the exhaust that a portion of vapor condenses to liquid from the exhaust, before the exhaust air is vented outside.

The following figure shows a relationship between the temperature of return water to the boiler and the boiler efficiency. To achieve the high efficiency rating with a condensing boiler, it is important to have the return water temperature from heating loop low enough for the boiler to effectively condense the combustion exhaust.

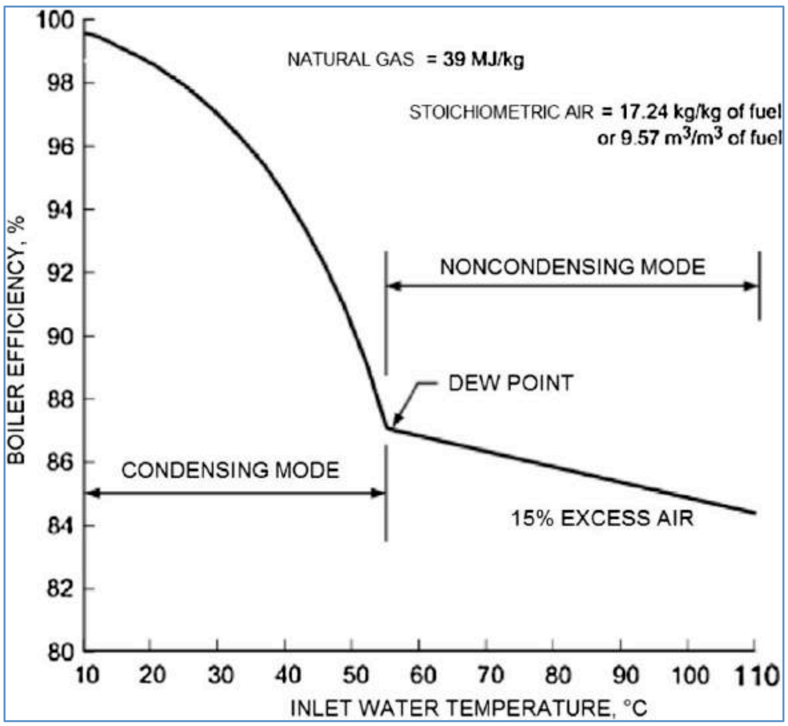

Figure 9: Characteristic curve for return water temperature and boiler efficiency (sciencedirect.com)

<u>Building Envelope Air Seal Improvement:</u>

There is an opportunity for certain farms to improve the air sealing of their heated building spaces. For farms that heat the building through the winter (e.g. a workshop space), a building that has a considerable exposure to winds in the winter across the roof and against walls will commonly experience high and low air pressures created in the attic space. For buildings without tight air sealing between the attic and the heated space, a low pressure in the attic can draw warm air out of the building through the attic, and draw cold air into the heated space from elsewhere in the attic and through wall areas that aren't tightly sealed, such as doors and windows. Improving the air sealing at one of the sample farms had an expected payback period in 4 years with a 30% IRR, including the cost of materials and labour to locate and reduce building air leaks using spray foam and caulking.

Building Space Heating:

There are two main requirements for space heating at the beekeeper facilities. The hot room gets heated in the summer (at all sample farms). Farms also have heated building spaces through the winter, either used for winter indoor work (e.g. workshop) or just to keep the in-floor heating pipes and concrete above freezing temperature to reduce risks of damaging the concrete floor or in-floor pipes.

Most hot rooms at sample farms were heated with an in-floor heating zone from a natural gas boiler during the honey extraction period (~2 months per year). One of the sample farms used a natural gas unit heaters and one farm used boiler-heated fan-coil units hanging from the ceiling (see example figures to the right). Most of the heat loss from the hot room space is through hive heating. Hives are brought into the hot room, heated by the air in the hot room, and then removed to the extraction line room.

Figure 11: Gas unit heater (hanging unit)

Figure 10: Hot water fan-coil

One of the farms had a low-efficiency boiler (e.g. 80% AFUE), which could be replaced with a high-efficiency boiler qualifying for a FEAP rebate, with an 8-year payback period and 7% IRR.

The average energy cost of space heating at sample farms (primarily natural gas boilers) was $0.423/hive. Based on recommended improvements for sample farms to reduce space heating energy consumption (including air-seal improvements and boiler efficiency), the average energy cost savings estimated for the sample farms was 10.9% ($0.046/hive). The recommended improvements had an average payback period of 3.2 years, and 44% IRR.

Based on an estimate of 256 commercial beekeepers in Alberta with an average farm size of 1114 hives, with an average space heating energy cost savings of $0.046/hive, this could save the Alberta beekeeping industry a total of $13,151/year.

4.9. Circulators (Hydronic Heating)

Hot Water Circulators:

The most common circulators at the farms were used to supply hydronic hot water space heating from a natural gas boiler to different areas or zones of the building. Most of the circulators observed were controlled by thermostats, which ensure that circulators shut off automatically when heat is not needed. Most of the thermostats were single-speed, or manual three-speed (see example figure to the right), with PSC (permanent split capacitor motors).

Figure 12: 3-speed circulator (single speed)

None of the farms had installed high-efficiency variable-speed pumps with ECM (electronically commutated motors). ECM pumps are more energy efficient than PSC pumps, but PSC pumps cost less to purchase than ECM pump. The relatively short operating hours per year for circulators at the sample farms were not high enough to provide enough energy savings to justify the investment to replace PSC pumps with ECM. However, for larger circulators (e.g. over 100W) that need to run significant hours over the year (e.g. more than 2000 hours/year), ECM circulators can have a positive return on investment as an upgrade from PSC, to replace an existing operating PSC circulator or as an incremental cost upgrade when replacing an existing PSC circulator at the end of its life. When installing a new boiler, there is a government rebate through the FEAP program [1] for ECM circulators (which are intrinsically controlled) when installed with a boiler (as a retrofit).

An example of an intrinsically controlled ECM circulator is the Grundfos Magna3 (see example figure to the right). The variable speed circulator monitors water pressure and water temperature and adjusts the circulator speed to slow down and save power when hot water is not required (intrinsic control). Even at full speed the ECM technology uses less energy than a circulator with a PSC motor.

Figure 13: Grundfos Magna3 variable speed circulator

The typical energy savings associated with changing from a single-speed circulator to an ECM variable speed circulator such as Grundfos Magna3 is estimated as 40-75% savings [18].

4.10. Lighting

The lighting energy consumption at the sample farms, by lighting type, is shown in the following figure.

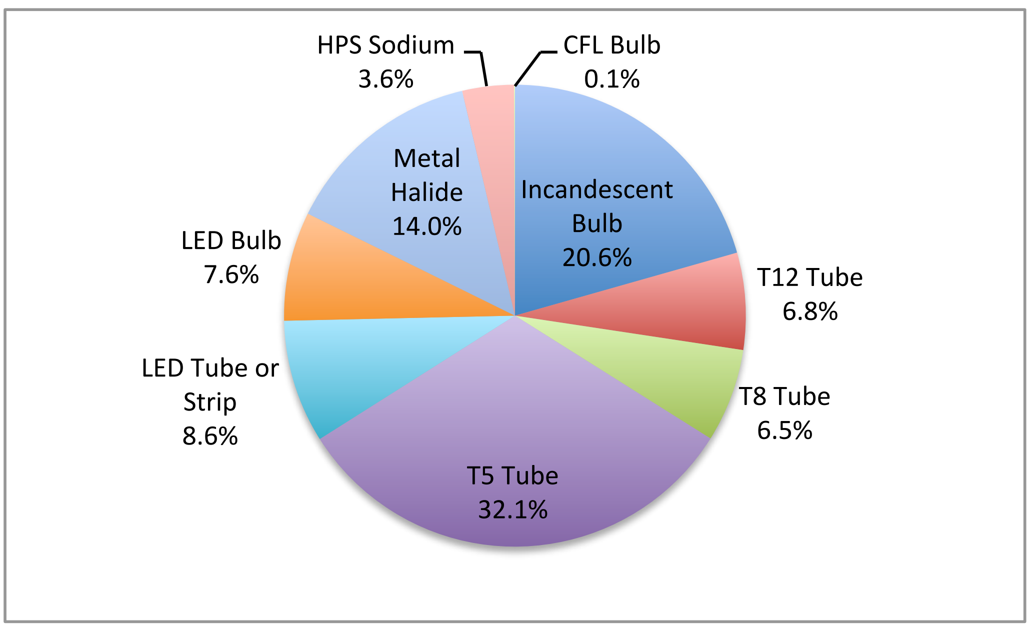

Figure 14: Lighting technology energy consumption at sample farms

The average energy cost of lighting at sample farms was $0.141/hive. Based on recommended improvements for sample farms to upgrade to more energy efficient lighting and controls, the average energy cost savings estimated for the sample farms was 35.1% ($0.049/hive). The recommended improvements had an average payback period of 3.2 years, and 44% IRR.

Based on an estimate of 256 commercial beekeepers in Alberta with an average farm size of 1114 hives, with an average energy cost savings of $0.049/hive, this could save the Alberta beekeeping industry a total of $14,106/year.

Each lighting technology is described in more detail in the following sections.

Fluorescent Tubes

Figure 15: Fluorescent T8 Tube Fixture

Fluorescent tubes made up 45.4% of lighting energy consumed at sample farms. The sizes of tubes in use were T12 (7%), T8 (7%), and T5 (32%). The T8 tubes (see example figure to the right) are narrower (1" diameter) and more efficient than the T12 tubes (1.5" diameter). T5 tubes are 5/8" diameter and are more efficient than T8 and T12. The typical T12 life is 10,000 hours and 20,000 hours for T8 and T5. LED tubes last longer and are more energy efficient than a fluorescent tubes but at the sample farms LED tubes were economical to replace T12 and T8 tubes, but not T5 due to the smaller energy savings potential of LED tubes versus T5.

Figure 16: Fluorescent light ballast

Fluorescent tube fixtures have a ballast (see example figure to the right) to regulate the power provided to the tubes. Typically when switching from a T12 to a T8 tube, the tubes will fit in the same fixture but the light fixture ballast needs to be changed from T12 to T8 to ensure proper tube life and lighting performance. In this case, it will be more economical to install LED tubes without ballasts, than to install new ballasts with T8 tubes.

The advantage of fluorescent tube lighting is the low cost of the tubes compared to other lighting options. The disadvantages of fluorescent tube lighting are that the life of the tube and the ballast are shorter than the life of LED tubes, and require maintenance to replace. Also, the fluorescent tubes contain mercury, which is harmful to the environment and to people if a tube gets broken at the site.

LED Tubes (and LED Strip Fixtures):

Figure 17: LED tube

LED tubes (and LED strip fixtures) made up 8.6% of the lights observed at the sample farms.

There are LED tubes designed to fit in the same fixture as a fluorescent T12 or T8. LED tubes are available as a type that works with and relies on the existing fluorescent ballast, and the other type of LED tube does not require or work with a ballast. LED tubes are more energy efficient and they last longer than T12 or T8 fluorescent tubes. The typical life of an LED tube is 40,000 hours (2-4 times longer than fluorescent tubes).

LED Bulbs:

Figure 18: LED bulbs (A-type)

LED bulbs made up 7.6% of the lighting energy consumed at sample farms. LED bulbs use less power than CFL or incandescent bulbs to make the same amount of light (measured in lumens per watt). The typical life of an LED bulb is at least 25,000 hours (25 times the life of incandescent and 2.5 times the life of CFL).

Incandescent Light Bulbs:

Incandescent bulb, including halogen bulbs (see example figures to the right), made up 20.6% of the lighting energy consumed at the sample farms. Incandescent bulbs are typically 40W, 60W, or 100W for smaller room applications, and halogen bulbs are typically over 200W and used lighting larger rooms or parking areas. Incandescent bulbs are the least efficient lighting technology and they can be replaced with CFL or LED bulbs that screw into the same fixture, which are designed to provide equivalent light as incandescent bulbs, while using 70% to 80% less energy. The typical incandescent life is 1,000 hours.

Figure 19: Incandescent bulb 100W

Figure 20: Halogen bulb 300W

Metal Halide and High-Pressure Sodium Bulbs:

Metal halide (MH) bulbs and high-pressure sodium (HPS) bulbs made up 17.6% of lighting energy consumed at sample farms. MH and HPS are types of lighting technology called "gas discharge" (see example figure to the right). LED lighting is commonly more energy efficient than MH and HPS lighting due to the directional design of LED fixtures directing light to where it is needed, while the MH and HPS bulbs cast light in many directions (omnidirectional) which requires larger capacity bulbs to provide enough light to where it is needed.

Figure 21: HPS Bulb

LED bulbs and LED integrated fixtures (see example image to the right) use less power than MH or HPS bulbs to make the same amount of light (measured in lumens per watt). The typical rated life of an LED high bay fixture is 50,000 hours, compared to 15,000 hours for MH and 24,000 hours for HPS [18].

Figure 22: LED High-Bay Fixture

Compact Fluorescent Light Bulbs (CFLs):

CFL bulbs made up less than 1% of the lighting energy consumed at sample farms. They consume less power to make the same amount of light as an incandescent bulb. One of the disadvantages of CFL bulbs is that they contain mercury, which is harmful to the environment and to people if a bulb gets broken at the site. CFL bulbs also use more power than LED bulbs to make the same amount of light. The typical life of a CFL is 10,000 hours.

Figure 23: CFL bulb

4.11. Honeycomb Uncapper Knife Heaters

Uncapper Knife Heaters:

All of the farms visited had an uncapper machine with knives that scrape or cut the caps off the honeybomb frames to allow the honey to flow out of the frames in the extraction spinner.

Figure 24: Uncapper with Hot Water Knife (mannlakeltd.com)

56% of farms used uncapper machines with an electric-hot-water heated knife.

44% of farms did not heat the uncapper knife and reported that the honeycomb was warm enough coming out of the hot room that the uncapper knife did not need to be heated.

Most of the electric-hot-water knife heaters can be fed with hot water from the existing natural gas boiler system, which was not cost effective as a retrofit for farms due to the relatively high cost of plumbing the boiler hydronic system to knife heaters. However, the most energy efficient practice observed was to avoid heating the knives at all and instead rely on the hot room heating, which was using natural gas as the heat source at all the sample farms.

4.12. Honey Pump Motors

The honey pumps at sample farms were a using combination of single-speed single-phase motors and also variable-speed three-phase motors. In some cases, single-speed pumps were not ideally sized (over-sized) for the steady flow rate of the extraction line, which caused fluctuation in the honey flow to the honey heater and spin-float. The energy savings potential of switching the pump motor to a three-phase motor with a variable speed drive could be 10% or more, but that energy savings did not justify the cost of changing the existing motor to variable speed. Most farms were using variable speed honey pumps (see example figure to the right) to achieve a steady flow rate from the extraction line to the honey heater and spin-float. This is a more energy efficiency technology but it is the most common pumping technology for the processing requirements, not for energy efficiency savings.

Figure 25: Honey Pump, 3" Progressive Cavity, Variable Speed Drive (cowenmfg.com)

4.13. Honey Heaters and Honey Separators

Honey Heating with Natural Gas Boiler to Reduce Electric-Heating Costs

100% of the sample farms were using a honey heater for the purpose of achieving honey separation from wax and other debris. The honey heating equipment designs observed were a wall-mounted tube heat exchanger (78% of farms) or a heated honey sump separator tank (22% of farms). These honey heaters use tubes (or a jacket) containing water (or vegetable oil) that exchanges heat into the honey. 67% of the farms were heating the honey with electricity and 33% of the farms had retrofit the honey heating equipment to use natural gas boiler heat.

There is an opportunity for farms to retrofit existing electric honey heaters with heating loops from an existing natural gas boiler at the farm. The boiler water can be used to go through a heat exchanger to heat the water jacket, or the boiler water can circulate directly through the jacket (subject to food safety considerations). The temperature range required from boilers for the honey heaters and existing in-floor heating (space heating at most farms) is typically below 49C (120F), so most existing boilers are capable of providing this temperature.

The average energy cost of honey heating at the applicable sample farms was $0.077/hive. Based on recommended improvements to retrofit existing electric honey heaters with heating from existing natural gas boilers, the average energy cost savings estimated for the sample farms was 45.2% ($0.035/hive). The recommended improvements for honey heater upgrades had an average payback period of 8.8 years, and 9% IRR.

Based on an estimate of 256 commercial beekeepers in Alberta with an average farm size of 1114 hives, with an average honey heater energy cost savings of $0.035/hive, this could have a total savings for the Alberta beekeeping industry of $9868/year.

Honey Heater (Tube Heat Exchanger) for Spin Float Separator:

The honey heat exchanger (see example in the figure to the right) has electric heating elements that heat a circulated oil loop, which exchanges heat into the honey to reach a honey temperature of 35C to 41C (95F-105F). The purpose for honey heating is to achieve the best results in the honey spin-float separator [18].


Figure 26: Honey Heater (Heat Exchanger) (cooknbeals.com)

Honey Separator Spin Float:

Honey extracted from uncapped combs typically contains pieces of wax and other debris. A honey separator is then used to separate the honey from those other particles.


Figure 27: Spin Float Honey Separator (cooknbeals.com)

78% of the farms visited used spin floats for separating honey, which are the industry standard among commercial beekeepers in Alberta due primarily to a very high rate (98% or more) of honey separation from the wax. The spin float uses a motor to spin a drum where the honey and wax separates. The wax falls to the bottom of the drum then out into a barrel below. The honey spins centrifugally against the sides of the drum away from the wax, collects in a small tank, then gets pumped to honey storage tanks.

The motor that spins the drum at some sample farms was a single-speed single-phase motor, and at some farms it was a variable-speed three-phase motor typically including a phase-converting VFD (variable frequency drive) for speed control. The VFD and three-phase motor typically consumes less power than the single-phase motor, which can be 10% or greater depending on the specific motor characteristics versus the loads put on the motor. However, the energy savings is not expected to justify the cost of retrofitting an existing spin-float with the VFD kit (over $4,500 CAD) based on the relatively short operating hours per year (~ 2 months per year).

Honey Separator Sump Tank with Honey Heater:

Figure 28: Sump Honey Separator (legaitaly.com)

22% of the farms visited used sump separator tanks instead of the spin float. The sump tank has baffles (or ventricles) that catch wax and debris that float to the surface of the honey, while the honey flows underneath each baffle. The floating wax gets skimmed off the top surface of the honey using a skimming tool by hand. Honey gets pumped out of the sump tank to honey storage tanks. This sump technology is a lower up-front cost option than the spin-float, but the sump typically does not get as much honey out of the wax as the spin float, and the skimming process requires more labour attention than the spin float. Due to honey recovery and labour costs, the spin float is the industry standard for commercial applications.

5. Farm Criteria for Technology Improvement Economics

The table below shows a summary of the current technology with identified criteria for farm characteristics that typically impact the economics for implementing energy efficiency upgrades.

Table 1: Farm Criteria for Technology Improvement Economics

Indoor Overwintering Ventilation Fans and Controls			
Focus	**Name of Technology**	**Description and Purpose**	**Criteria for most economical implementation**
Fresh Air Temperature Fan Control	Climate controller with fresh air temperature sensor.	Prevent ventilation fans from running for cooling when fresh air temperatures are too warm to provide cooling (e.g. when fresh air is warmer than overwintering room air).	Existing climate controller is capable of fresh air temperature sensor input, and capable of fan control logic based on fresh air temperature compared to overwintering room temperature.
			Farm has experienced warm days in winter when ventilation fans ran for cooling but fresh air was warmer than overwintering room air.
Variable Speed Exhaust Fans	Electronically Commutated Motor (ECM).	Fan electronics convert AC power to run a brushless DC motor for better energy efficiency than VFD or triac speed controls. Reduce fan power consumption at low speeds.	Use for air recirculation or for minimum winter ventilation (24/7 through winter).
			Existing room ventilation system has variable speed fans that run significant hours per year.
			Existing fan controls have 0-10V (or 4-20mA) signal outputs available for fan control (avoids the cost of upgrading fan controls).
			Winter fan sizes 45cm or larger (faster payback when replacing larger variable-speed fans).
			Existing variable speed fans are triac-controlled. Not VFD controlled.
			Existing fans do not use significantly less power at minimum speed than they use at maximum speed.

Space Heating and Water Heating			
Focus	**Name of Technology**	**Description and Purpose**	**Criteria for most economical implementation**
Boiler Efficiency	High-efficiency modulating condensing boiler	Upgrade from non-condensing boiler (below 86% efficient) to condensing boilers (95% efficiency or above).	Existing boiler is 80-82% efficient (or less).
			Existing boiler capacity is located in one room, not multiple small boilers in different locations.
			The return-water temperature to the existing boiler is (or can be) below 120 deg F, which is common for in-floor heating.
Waterline freeze-prevention	Bury below frost line. Eliminate electric heat trace.	Bury waterlines underground below frost depth. This uses the heat from the ground to prevent waterlines from freezing.	Existing waterlines have frozen in the past.
			Waterlines are above ground or buried too shallow in the ground where the ground freezes.
			Existing heat trace is electric-heated.
Domestic Hot Water Heating	On-demand tankless hot water heater (condensing)	Replace an existing hot water tank with a tankless condensing hot water heater to reduce heat losses through tank walls into non-heated space and to reduce heat loss through combustion exhaust.	Existing domestic hot water tank is natural gas (non-condensing), or electric. Gas is less expensive heat energy source than electricity.
			Domestic hot water consumption is considerable year-round (e.g. showers and washing machines).
			Existing hot water tank is in a non-heated space.
			Existing hot water tank does not have power-vented exhaust.
Building Heat Loss through air leaks at ceilings (attic) and exterior walls.	Heated space air sealing	Add air-sealing materials (e.g. spray foam, weather strips, caulking) to reduce air leaks into attic and walls. Reduces heating costs.	On cold winter days and on windy days, air drafts are notable at man-door entry to the building and heated spaces.

Focus	Name of Technology	Description and Purpose	Criteria for most economical implementation
Hot Water Circulator Pumps	Variable speed ECM circulator pump.	Automatically reduce circulator speed when heat is not required. Save power from lower circulator speed and from high-efficiency ECM technology.	Existing pump runs all year at a constant speed.
			Existing pump draws more than 300W.
			Requirements for hot water circulating significantly reduce or fluctuate during certain months of the year.

Lighting			
Focus	**Name of Technology**	**Description and Purpose**	**Criteria for most economical implementation**
LED Tubes	LED tubes (e.g. plug-and-play with ballast or bypass-ballast)	LED tubes are more efficient than fluorescent tubes.	Existing light is T8 or T12 fluorescent.
			Light is used daily.
			Light is used more than 120 hrs/year.
			Instant-on without flickering is preferred by users.
LED Bulbs	LED bulbs (e.g. E26 base)	LED bulbs are more efficient than CFL and incandescent bulbs.	Existing light is incandescent (40W-80W) or CFL (13W-16W) or halogen (100W-300W).
			Existing light is used more than 120 hrs/year.
LED Integrated Fixtures	LED integrated fixtures (e.g. wall-pack, high-bay or street)	LED integrated lights are more efficient than halogen incandescent.	Existing light is incandescent (40W-80W) or CFL (13W-16W) or halogen (100W-300W) or metal halide (lower efficiency versions) or high-pressure sodium (lower efficiency versions).
			Light is used more than 120 hrs/year.
Lighting Automation	Lighting timers and motion sensors	Lighting timers or motion sensors can be set to turn certain lights off when the light is not required.	Light is left on longer than required. For example, people may regularly forget to turn lights off, or lights sharing one circuit and switch may all stay on as a group even though some of those lights don't need to be on for as long as others.
			Lighting duration requirements are predictable and consistent (for a timer).
			Lighting is indoors, which would allow a low-cost indoor rated motion sensor switch to be used.

Process Heating			
Focus	**Name of Technology**	**Description and Purpose**	**Criteria for most economical implementation**
Honey Heating	Honey heater (heat exchanger) heat source conversion from electric natural gas	Convert existing electric-heated honey heaters to use boiler heat (natural gas). Natural gas is a lower cost heat source than electricity.	Existing honey heaters use electricity. Also called, honey heat exchanger, or heated honey sump separator tank.
			The honey heater is used significantly in the year (e.g. farm size over 1000 hives).
			Existing boiler location and capacity is sufficient for providing a heating loop (waterlines) to the honey heater.
Wax Melting Heat Source	Wax melter heat source conversion from electric to natural gas	Convert existing electric-heated wax melters to use boiler heat (natural gas). Natural gas is a lower cost heat source than electricity.	Existing wax melters use electricity.
			Existing boiler has the capacity and location to provide heating lines to the wax melter area.
			Existing wax melters are not required to move around regularly in the building. It is more challenging to move or disconnect water lines than electrical cords.

Pressure Washer Heating			
Focus	**Name of Technology**	**Description and Purpose**	**Criteria for most economical implementation**
Pressure Washer Heating	Domestic hot water pre-heat of diesel pressure washer supply	Add pre-heated water supply to a diesel pressure washer. Save on diesel costs.	Existing pressure washer uses a cold water supply and heats the water to with a diesel burner.
			Existing domestic hot water location is sufficient to reach the diesel pressure washer using a water hose.

Appliances			
Focus	**Name of Technology**	**Description and Purpose**	**Criteria for most economical implementation**
Clothes Dryer Heat Source	Natural gas clothes dryer	Choose a natural gas clothes dryer instead of electric-heated when installing a dryer. Natural gas is a lower-cost heat source than electricity.	Existing natural gas lines have sufficient capacity and proximity to provide natural gas to the clothes dryer location.
			The farm does 3 or more per week of laundry with an existing electric dryer.

6. Energy Bills

6.1. Electricity Bills

The charges on the monthly electricity bill for a farm consist of the following four types of charges.

Energy Charge:

The amount of energy consumed in the month is measured in kilowatt-hours (kWh) by a meter on site. The energy price is applied as $/kwh. The applicable energy price for a bill can come from either a contract (negotiable with retailers), a market price, or regulated rate option (RRO) price.

Contract pricing applies when a farm has an agreement with the energy retailer to buy a certain amount of power per month (a "block" of kWh) at a fixed price for a certain time period. If the farm uses more than the contract block of power in the month, the additional power consumed is billed at the fluctuating market price ("pool"). If the farm uses less than the contract block of power in the month, the excess power is sold to the power pool at the fluctuating market price. The farm may get a credit on the bill or need to pay the difference between the farm's block price and the market price. The farm will pay the contract block price plus the "cost of retail" which includes any pool trading charges and the power line loss of energy before the power reaches the meter on site. Those charges should be included when comparing contract pricing to RRO pricing because RRO pricing includes those costs of retail.

Market pricing applies when the farm chooses to buy all power consumed at the fluctuating market price, plus the cost of retail, which includes power pool trading charges, line losses of energy before it reaches the meter at the site, and a markup to cover the retailer's costs and margin.

RRO pricing (Regulated Rate Option) applies when the farm selects RRO pricing or if the farm doesn't select a retailer or pricing arrangement, the RRO price applies by default. RRO prices fluctuate each month because they are based on short-term market pricing.

Administration Fee:

The admin fee covers the costs related to billing for electricity and providing customer service. This fee is fixed and does not depend on the amount of energy consumed over a month.

Transmission and Distribution Charges**:**

Transmission and distribution charges cannot be negotiated. The rate schedule type can sometimes be changed if the farm qualifies for more than one pricing schedule from the wire service provider but the wire service provider typically helps the farm choose the pricing schedule type to minimize the charges for the farm.

The transmission charge recovers the costs of owning and operating high voltage lines that carry electricity to the substation transformers.

The distribution charge recovers the costs of owning and operating the lower voltage lines that carry electricity from transformers near the site to the meter at the site.

The transmission and distribution charges are calculated differently based on the site service size and the wire service provider for the farm. The charges can be based on the amount of energy consumed in the month ($/kWh), and the "billing demand" as the maximum amount of power consumed in a short time frame (kVA), and fixed daily or monthly charges.

These charges are calculated by the wire service provider for the site and communicated to the retailer to include on the bill.

These charges can be partially reduced by installing renewable energy generation.

6.2. Natural Gas Bills

The charges on the monthly gas bill for a farm typically consist of the following charges.

Energy Charge:

The price for gas is typically negotiable with competitive retailers, although negotiating options can be unavailable depending on the supply of gas. For example, Co-Op gas providers would typically have less negotiating options and less availability of competitive retailers.

The amount of energy consumed in the month is measured in gigajoules (GJ) using a meter on site. The gas price is applied as $/GJ. The applicable energy price for a bill can come from either a contract or a regulated rate.

Contract pricing is typically available from "competitive retailers" and applies when the farm has an agreement for a fixed price for gas over a certain time period.

Regulated rate pricing applies if the farm has chosen a regulated rate provider as the gas retailer. Regulated rate providers are not allowed to make a profit on the cost of gas. They can only recover costs of the gas and other non-energy related costs though charges based on the customer's gas consumption.

Administration Fee:

The admin fee covers the costs related to billing for natural gas and providing customer service. This fee is fixed and does not depend on the amount of energy consumed over a month.

Delivery Charge:

The delivery charge recovers costs of transmission and distribution pipelines to transport the gas to the site. The charge is based on the amount of energy consumed in the month ($/GJ).

6.3. Bulk Delivery Bills for Diesel, Gasoline, and Propane

Diesel, gasoline, and propane are typically stored in tanks at the farm. The tanks get refilled periodically. The charges for fuel are typically billed as dollars per liter.

The delivery services for refilling the on-farm bulk tanks are billed either as a variable charge per liter, or as a flat charge per delivery. Either way, there are very few "fixed" energy costs associated with the consumption of these fuels, such as administrative fees (see natural gas bills section).

7. Conclusions

Energy efficiency improvement recommendations were given to the farms visited, with positive rate of return on investment ranging from 2 years to 9 years payback, and internal rate of return on investment (IRR) in the range of 7% to 182% over the economic life of the implemented improvement.

The recommended energy improvements at the sample farms are expected to reduce the average annual farm energy costs from $11.566/hive to $10.839/hive, which is an energy-cost savings of 6.3% or $0.727/hive. The average sample farm size was 5365 hives/farm with an average energy-cost savings potential of $3,900/year. The average energy savings by energy source would be $1029/year (0.192/hive), natural gas $11/year ($0.002/hive), propane $35/year ($0.007/hive), and diesel & gasoline $2825/year ($0.527/hive).

Based on an assumption of 256 commercial beekeepers in Alberta with 285,300 hives and an average farm size of 1114 hives/farm, with a similar energy efficiency cost savings potential as the sample farms average, the energy-cost savings would translate to an industry total of $207,413 per year.

The estimated GHG emissions reduction associated with potential energy efficiency improvements across all commercial beekeeping farms in AB could be 8.1% or 709 tCO2e/year.

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