DEMONSTRATION OF ENERGY-SAVING DEHUMIDIFICATION IN ONTARIO GREENHOUSES

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Background

Maintaining an optimum microclimate is essential for greenhouses to improve crop productivity; this requires high fuel consumption and results in significant emissions of greenhouse gases into the atmosphere. Greenhouse heating primarily uses natural gas, but a substantial portion of this heat is lost when vents are opened to manage high relative humidity levels and regulate air quality. This air exchange with outside is essential to prevent high-humidity related diseases and physiological disorders in the crop. Therefore, this project will evaluate energy recovery dehumidification technologies that largely circumvent greenhouse ventilation and associated heat losses, and substantially reduce fossil fuel consumption in the greenhouse sector.

Objectives

1. To provide greenhouse growers with scientific evaluation of energy recovery dehumidification technologies at a commercial scale, compared to traditional growing methods over full-year production (e.g. energy cost/savings, yields, etc.);
2. To refine, adapt, scale-up, integrate the total heat recovery (ERV) system into the commercial vegetable greenhouse;
3. To develop greenhouse climate control strategies using energy recovery dehumidification and ERV systems to increase energy efficiency in year-round greenhouse vegetable production;
4. To evaluate improvement in air quality as a result of the energy recovery dehumidification technology installation at the commercial greenhouse.

Limitations

1. The trials were conducted in commercial greenhouses within existing control strategies
2. Test zones often differ in area and crop canopy size
3. The location of the units are not always ideal
4. The areas of the test zones are larger than the manufacturer's recommendations
5. The greenhouses are not fully closed at night
6. The results were not comparable between the technologies since they were tested at different locations.

Ventilated Latent Heat Converter – VLHC system

➢ **Unit info:**

i. condenses up to **20 L/h** of moisture
ii. hot water system required and **2.4 kW** of electricity
iii. recommended to be used as a primary heating source
iv. captures and neutralizes mold spores

➢ **Findings:**

i. energy savings in cold season and during all heating hours
ii. remove **0.5-0.6 liters of water per kWh** (sum of hot water energy and power consumption) or **$0.08/L** in this specific case
iii. calculated average U-value of **4.8 W/m²/°C**
iv. provide heat into the greenhouse

		In RH (%)	Unit regen (kWh_th)	Unit power (kWh_e)	Heat (kWh_th)
Mar.12th – 26th 2019 (2wks)	ON	84.3	3070	368	14801
	OFF	87.7	--	--	20136
	Savings (%)	--	--	--	**26.5**
Jan.13th – Feb.07th 2020 (3 wks)	ON	89.5	8707	1146	51964
	Control	87.9	--	--	75485
	Savings (%)	--	--	--	**31.2**

* Unit regen (kWh_th) is the hot water thermal energy required for regeneration process
** Unit power (kWh_e) is the unit electricity consumption
*** Heat energy (kWh_th) = greenhouse heat energy + unit regen
**** The price for thermal energy is $0.022/kWh and $0.15/kWh for electricity

Mechanical Refrigeration Dehumidifier – MRD system

➢ **Unit info:**

i. condenses up to **45 L/h** of moisture
ii. can be positioned on the ground
iii. massive energy savings in fully closed greenhouse

➢ **Findings:**

i. energy savings in both hot and cold seasons
ii. remove **4-4.5 liters of water per kWh** of electricity consumption or **$0.05/L** in this specific case
iii. calculated average U-value of **5.1 W/m²/°C**
iv. provide heat into the greenhouse
v. installation is easier but needs CSA certification

		In RH (%)	Unit power (kWh_e)	Heat (kWh_th)
Mar.12th – 26th 2019 (2wks)	ON	78.2	1450	15024
	OFF	81.3	--	20267
	Savings (%)	--	--	**25.0**
Nov 2019 (4 wks)	ON	88.0	7216	72727
	Control	92.1	--	94357
	Savings (%)	--	--	**22.9**

* Unit power (kWh_e) is the unit electricity consumption
** Heat energy (kWh_th) is the greenhouse hot water thermal energy required for heat
*** The price for electricity is $0.15/kWh

Air-to-air Heat Recovery Ventilation – HRV system

➢ **Unit info:**

i. the moisture removal capacity depends on the outdoor air conditions
ii. requires both indoor and outdoor ductwork

➢ **Findings:**

i. calculated average U-value of **5.7 W/m²/°C**
ii. more effective when the outdoor air is warm and dry
iii. may add the greenhouse heating load in cold season

		In RH (%)	Unit power (kWh_e)	Heat (kWh_th)
Mar.12th – 26th 2019 (2wks)	ON	76.1	560	28002
	OFF	70.8	--	28465
	Savings (%)	--	--	**1.6**
Jan.13th – Feb.07th 2020 (3 wks)	ON	81.6	250	81648
	Control	87.9	--	75485
	Savings (%)	--	--	**-8.2**

Note: The definition of Unit power (kWh_e), Heat energy (kWh_th), and the price of electricity are the same as of MRD system.

State Point Liquid Desiccant Dehumidifier – ERV system

➢ **Unit info:**

i. the pilot unit has two modes: dry and wet
ii. automatically transit between two modes
iii. wet mode works as liquid desiccant system, dry mode operates as heat exchanger
iv. remove up to **20 L/h** of moisture at wet mode
v. requires hot water system to regenerate desiccant

➢ **Findings:**

i. calculated average U-value at ERV zone of **14.5 W/m²/°C**
ii. remove **0.3-0.5 liters of water per kWh** (sum of hot water energy and electricity consumption) or **$0.21/L**

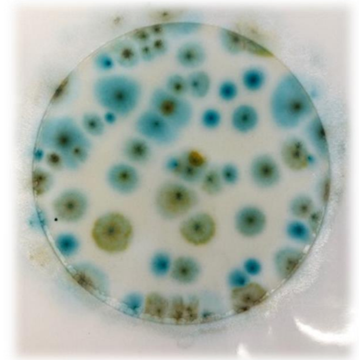
2019	Control		ERV				
	In RH (%)	Heat (kWh_th)	In RH (%)	Heat (kWh_th)	Regen (kWh_th)	Power (kWh_e)	Savings (%)
May	82.0	49092	83.4	38072	2137	548	**22.4**
Jun	77.5	78533	82.8	67279	5282	1408	**14.3**
Aug	76.1	12052	82.6	12077	1355	1064	**-0.2**
Sep	79.2	20960	83.6	22055	5603	1735	**-5.2**

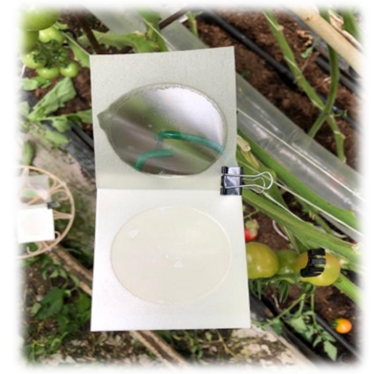
Note: * The definition of Unit regen (kWh_th), Unit power (kWh_e), Heat (kWh_th) are the same as of VLHC system.
** The price for thermal energy is $0.027/kWh and $0.15/kWh for electricity at this tomato greenhouse.

Air Quality Monitoring – three methods

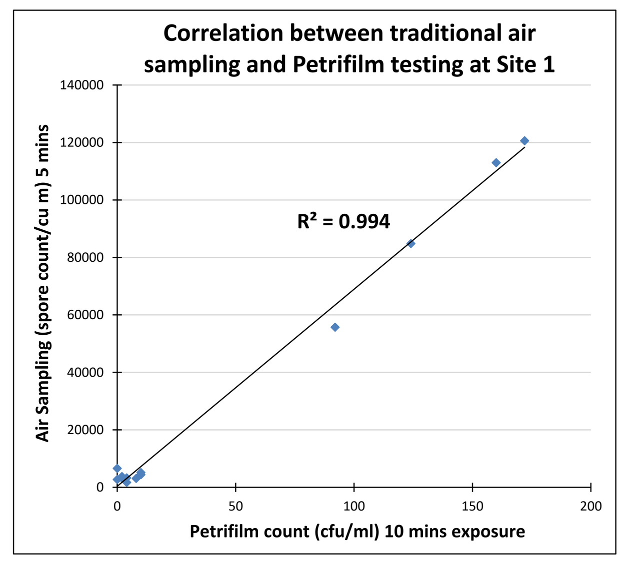
➢ **harmful gases measurement**
- MacView greenhouse gas analyzer

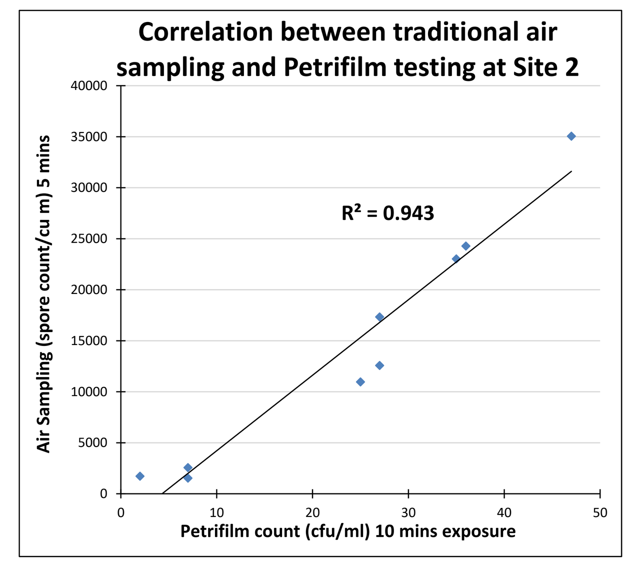
➢ **microbial air quality monitoring**
- 3M Petrifilm™ method
- Spore trap air sampling method





➢ **comparison between 3M petrifilm™ and spore trap air sampling method**





- good linear correlation between petrifilm results and air sampling results
- 3M Petrifilm™ is a cost effective and convenient way for detection and enumeration of viable fungal spores

Findings and Considerations

➢ Better RH is definitely possible – but optimizing is key.
➢ Energy savings could be achieved by using different dehumidification systems.
➢ The system can't just be installed as add-ons; they must be incorporated into the logic of the existing greenhouse environmental control systems in order to optimize energy savings.

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