Energy Efficient Food Storage Systems

Luke Doody & Ben Weil, PhD., UMass Department of Environmental Conservation; Building and Construction Technologies

Rationale: The market for local produce over the winter months is growing as winter CSA's and winter farmer's markets increase in popularity. To meet this growing demand farmers must be able to economically store produce for extended periods of time while maintaining produce quality. With these criteria in mind we set out to design and implement a working cooler that is more energy efficient and has an improved storage environment over conventional cooler models.

Research Goals: Our goals are to develop energy efficient food storage systems. Research thus far has been focused on using outdoor air and evaporative cooling to store produce that is ideally stored at cold temperatures and high relative humidity levels. Produce of this storage category includes but is not limited to: carrots, turnips, beets, cabbage and parsnips. Many farmers in New England already take advantage of the cold outdoor air temperatures during the storage months of October through March to reduce energy use. However outdoor winter air is very dry and creates a storage environment that can cause weight loss, shrinkage and decreased produce quality. By introducing humidity into the storage environment via a centrifugal humidifier we aim to improve the storage environment for the produce while also taking advantage of evaporative cooling to extend the number of hours of "free cooling" that are available.

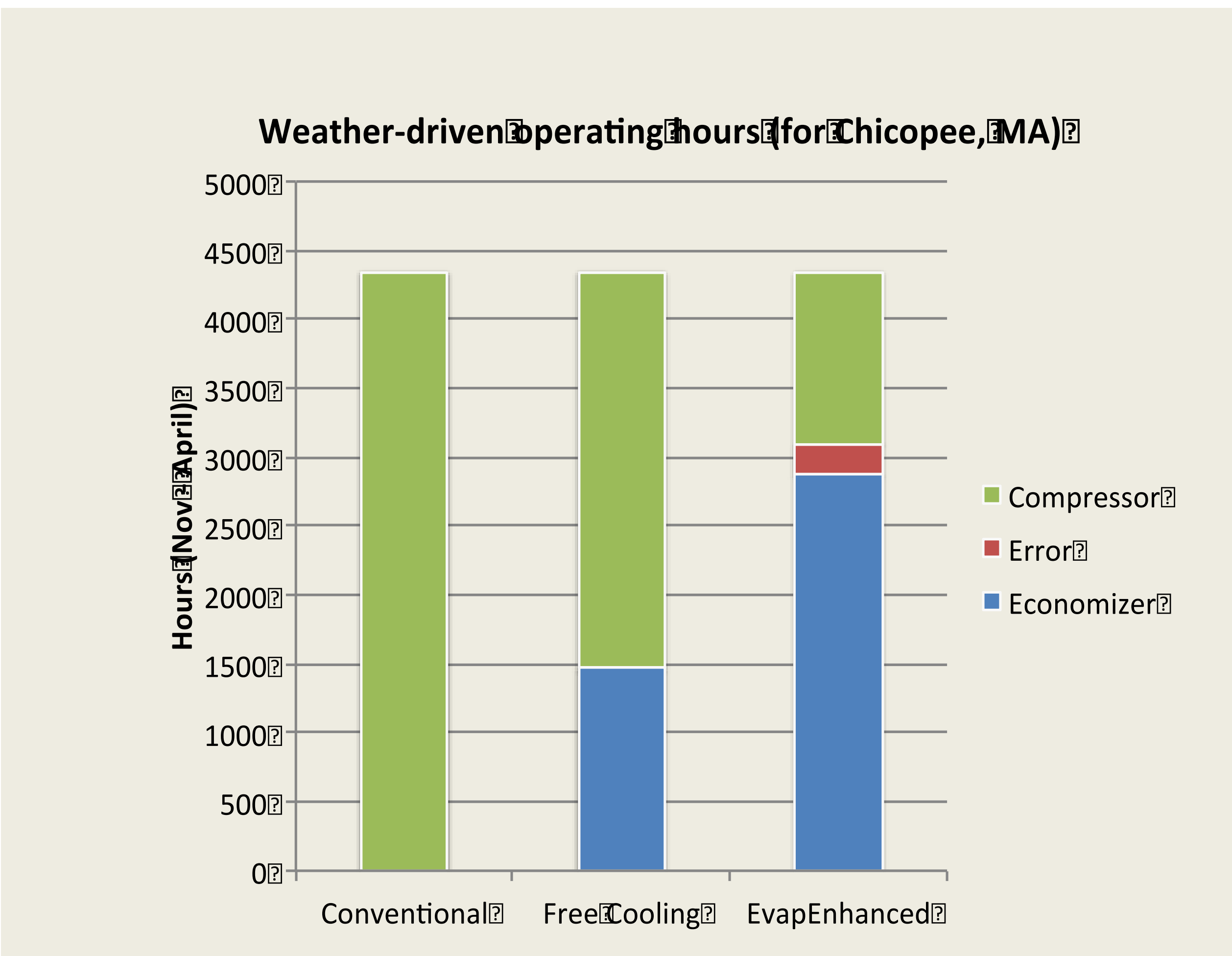
Treatments: We began research in the late winter of 2013 to establish the effectiveness of evaporative cooling in New England winters. We ducted outdoor air into two controlled test huts, one of which had a Humidisk 10 Centrifugal Humidifier and the other that was empty. In this experiment we were able to establish at what outdoor temperatures we could achieve acceptable refrigeration temperatures.

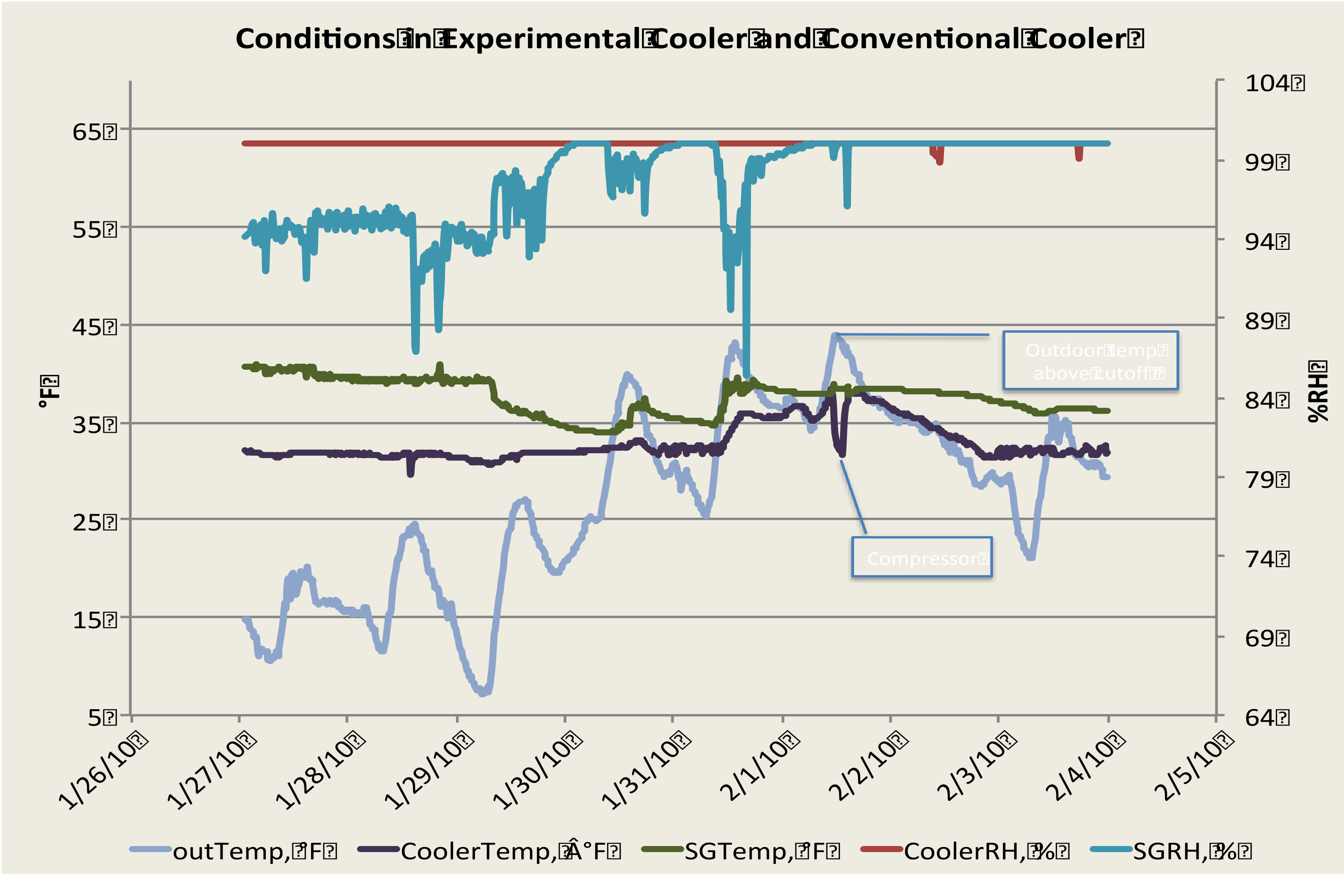
With the data gathered in our first experiment we implemented a full-scale working model of the Evaporative Cooling Enhanced (EvapEnhanced) System on an 8ft X 8ft X 8ft walk in cooler and stored produce over the following winter season of 2013-2014. The prototype cooler was fit with an outdoor fan that operated on two thermostats. One thermostat read outdoor air temperature and was set to turn on bellow 45˚F and the other that read the internal cooler temperature and turned on when temperatures reached 34˚F and off at 32˚F. The mechanical direct expansion (DX) cooling system of the cooler was wired through another thermostat that eliminated the need for the evaporator fan to run constantly. The DX system was set to turn on when internal temperatures reached 38˚F and off at 33˚F. A 70 CFM fan was used to circulate air when there was not need for the evaporator fan to operate. The same Humidisk 10 Centrifugal Humidifier was used as in our previous winter's experiment.

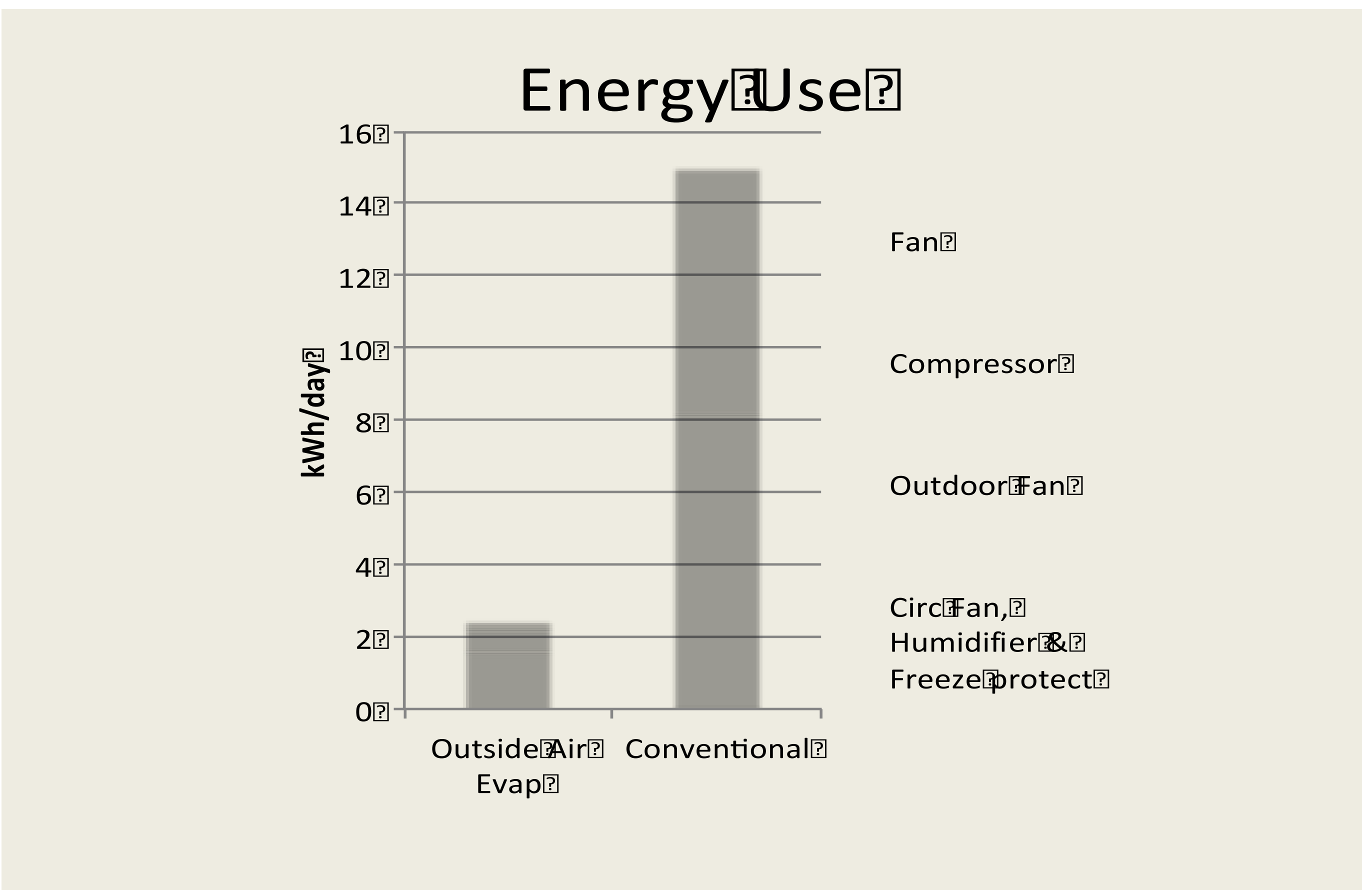
We collaborated with Simple Gifts Farm in North Amherst, MA and filled our cooler with roots for their winter CSA shares. We also stored carrots that were measured monthly for weight loss and sugar content in both our cooler and a similar cooler at Simple Gifts. Temperature, relative humidity and energy usage were measured throughout the winter at both locations and compared.

Results:

From our first set of experiments we were able to determine the number of hours of "free cooling" available using outdoor air only and using outdoor air with evaporative cooling.

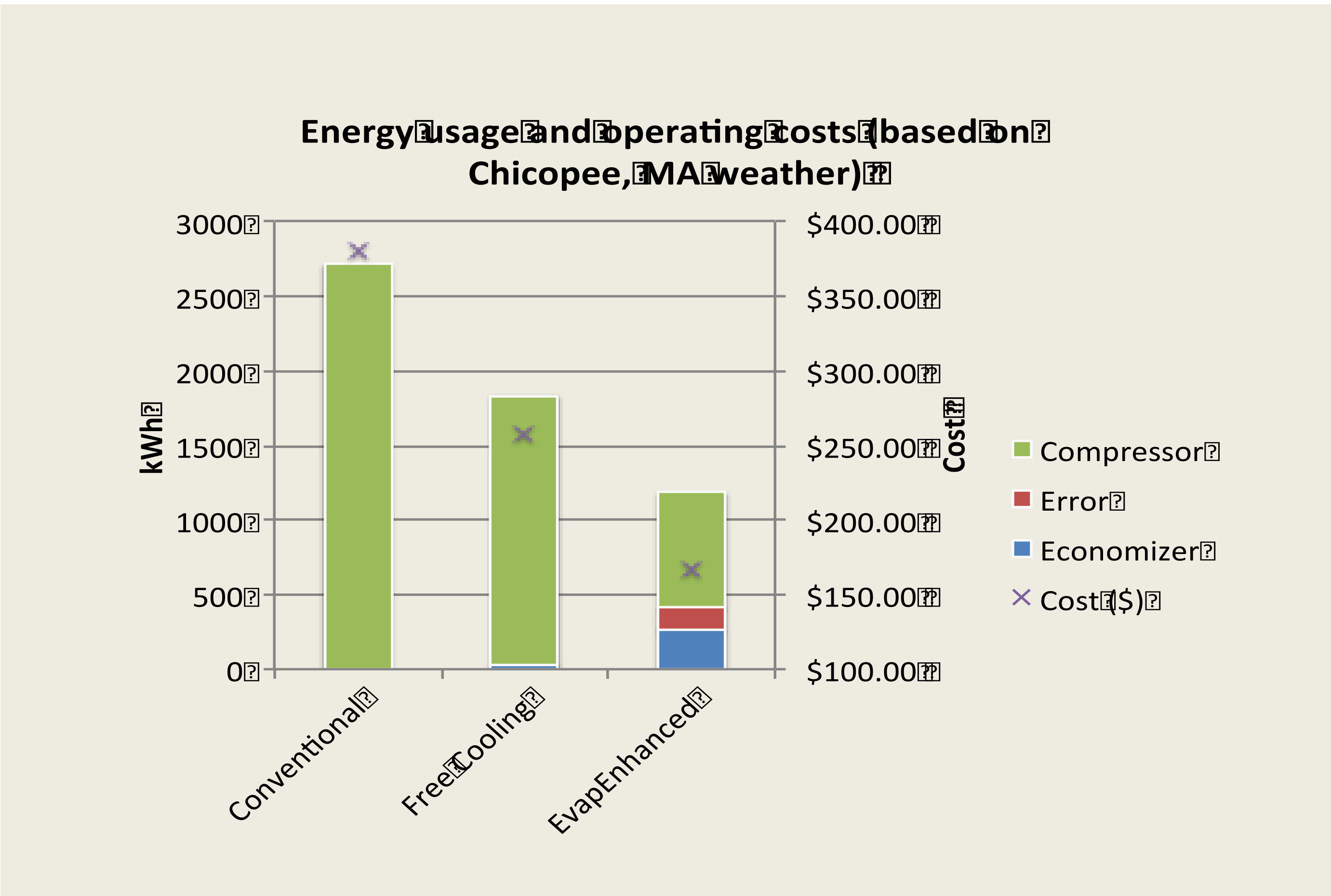



Conditions in Experimental Cooler and Conventional Cooler
°F
%RH
65
55
45
35
25
15
5
104
99
94
89
84
79
74
69
64
1/26/10
1/27/10
1/28/10
1/29/10
1/30/10
1/31/10
2/1/10
2/2/10
2/3/10
2/4/10
2/5/10
Outdoor temp above cutoff
Compressor
outTemp, F
CoolerTemp, Â°F
SGTemp, F
CoolerRH, %
SGRH, %


Energy Use
kWh/day
16
14
12
10
8
6
4
2
0
Outside Air Evap
Conventional
Fan
Compressor
Outdoor Fan
Circ Fan, Humidifier & Freeze protect

From our working model we were able to calculate the energy usage of our Evaporative Cooling Enhanced cooler compared to that of a conventional cooler. The conventional cooler used an average of 5 times more energy than our EvapEnhanced model.

Based on weather data from the Chicopee, MA weather station we calculated the estimated energy usage and operating costs of our system compared to conventional and “free air” only systems. The “free air” system has an estimated annual energy savings of $122. Our EvapEnhanced system has an estimated annual energy savings of $213. Humidifier savings are probably bigger at larger scales as our cooler was only 512 ft^3 and the mechanics of our set up can be applied to a cooler with a volume of 12,000 ft^3. These cost savings do not reflect the improved quality and weight retention of the produce. It can be assumed that with increased quality there will be increased marketability and therefore increased revenue.



First Cost and Simple Payback Period

Item	Cost	Economizer only
Humdifier	$900	N/A
Air intake fan	$200	$200
Circ. fan	$40	$40
Misc.	$100	$100
Total	**$1,240**	**$340**
Savings	*$213*	*$122*
Simple Payback	**2.91 Years**	**2.78 Years**

Pictures:


P-4
02/10/2014


02/10/2014


02/10/2014


02/10/2014


02/10/2014


02/10/2014

Many thanks to Simple Gifts Farm, The UMass Student Farm, The South Deerfield UMass Research Farm, UMass Agricultural Extension and the USDA

Publications will be made available in the coming months regarding this research. Further research is expected focusing on efficiently meeting the storage needs of other crops that are ideally stored in warm/dry and warm/humid environments.

Please direct any questions, comments or ideas concerning crop storage infrastructure, energy efficiency and construction to:

Luke Doody at ldoody@eco.umass.edu