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Increasing Supply and Quality of Local Storage Vegetables

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Summary

This project installed environmental monitoring equipment to improve storage conditions and ultimately the quality of 1,736 tons of winter storage crops at 9 farms throughout Vermont . The cumulative market value of these storage crops produced during the 2012-2014 growing seasons was $3.5 million. Improved storage monitoring led to better control of storage conditions, in part through automated notification to farmers when abnormal conditions were occurring. This allowed for prompt correction of problems such as open doors and failing or inoperative cooling equipment. Losses of storage crops (cull rates) were reduced from ~15% to ~5% of stored volume. Sixty-six energy efficiency measures were also implemented at 5 of these farms, saving a total of 40,269 kWh of electricity and $5,800 annually. The systems deployed have increased the confidence of growers to expand their winter storage of Vermont-grown vegetables, leading to an increased supply of local produce outside of the traditional growing and marketing season.

Project Overview and Situation

This project has improved the ability of Vermont vegetable farms to store crops such as beets, carrots, parsnips, potatoes, onions, squash and sweet potatoes , all of which have unmet demand in late winter when local supplies run out. The physiology of these crops allows them to be stored for many months after harvest if specific storage conditions are met. However, several distinct sets of conditions are optimal for different groups of crops, and achieving each condition requires careful control and monitoring of temperature and relative humidity in storage. Currently, Vermont's commercial vegetable farms rarely achieve the optimal conditions due to lack of sufficiently separated storage compartments, and lack of modern environmental monitoring and control equipment.

Below are the specific conditions for crops commonly stored into winter on Vermont vegetable farms.

- Cold and moist = 32°F and 90-95% RH. Beets, cabbage, carrots, parsnips and turnips.
- Cold and dry = 32°F and 65-70% RH. Garlic and dry onions.
- Cool and moist = 45°F and 90% RH. Potatoes.
- Warm and moist = 57°F and 85-90% RH. Sweet potatoes.
- Warm and dry = 55°F and 50-70% RH. Winter squashes, including pumpkins.

This project has direct relevance to Vermont's Farm to Plate Strategic Plan via goals 7, 12, and 22.

- Goal 7: Local food production—and sales of local food—for all types of markets will increase.
- Goal 12: A sufficient supply of all scales and types of on-farm and commercial storage, aggregation, telecommunications, and distribution services will be available to meet the needs of increasing year-round food production and consumer demand.
- Goal 22: Food system enterprises will minimize their use of fossil fuels and maximize their renewable energy, energy efficiency, and conservation opportunities.

Variable conditions during the three growing seasons of the project period resulted in fluctuating crop yields, , yet the monitoring systems installed were still seen by the participating growers as being instrumental to prolonged crop storage and maintenance of quality, regardless of production conditions. By improving the quantity, quality, and length of time that they can offer these crops, Vermont farmers increased their sales volume and also captured nominally higher prices. Stored crop sales increased from 423 to 742 tons (a 76% increase) from 2012 to 2014. The average price of all the stored crops was flat at $1.01 per pound, but the average price of all crops adjusted for the tonnage of each individual crop sold (weight average pricing) increased from $1.14 to $1.30 (a 14% increase) in the same period. Market relationships around local food have also been strengthened because buyers have had more consistent supplies of Vermont vegetables throughout the year. The trends associated with winter storage crop sales in this project are summarized in Table 1.

	2012	2013	2014
Stored Crops, ton	423	571	742
Year on Year Growth		35%	30%
Two Year Growth			76%
Storage Crop Value	$ 856,800	$ 1,169,260	$ 1,502,493
Year on Year Growth		36%	28%
Two Year Growth			75%
Average, $/lb	$ 1.01	$ 1.02	$ 1.01
Weighted Average, $/lb	$ 1.14	$ 0.88	$ 1.30
Two Year Growth			14%

Table 1 - Summary trends of winter storage crops among 9 farms in Vermont, 2012-2014.

The team expected to see greater change in unit prices of the storage crops over the project period. It is worth noting that although the overall mean of unit price remained essentially constant at $1.01 per pound, the weighted pricing was more variable. This latter price is the average unit price weighted by the volume of crop sold at a given price. For example, if 100 tons of potatoes sold for $1.00 per pound and 2 tons of garlic sold for $2.00 per pound the normal mean would be $1.50 per pound but the weighted mean would be $1.02 per pound. The latter more accurately reflects the cumulative value of product in storage. Based prices reported by growers we see weighted average unit prices vary from $0.88 to $1.30 per pound. Crop unit pricing and sales volumes are summarized in Table 2, Figure 1, and Figure 2.

Crop	2012		2013		2014	
	Average Price $/lb	Weight Averaged Price, $/lb	Average Price $/lb	Weight Averaged Price, $/lb	Average Price $/lb	Weight Averaged Price, $/lb
Beets	$ 1.19	$ 0.92	$ 1.23	$ 0.57	$ 1.30	$ 1.12
Onion	$ 1.40	$ 1.80	$ 2.00	$ 1.62	$ 1.96	$ 1.59
Leeks	$ 2.00	$ 2.00	$ 2.00	$ 2.00	$ 2.30	$ 2.30
Cabbage	$ 0.87	$ 0.97	$ 0.79	$ 0.49	$ 0.83	$ 0.59
Butternut	$ 1.09	$ 0.83	$ 0.69	$ 0.61	$ 0.46	$ 0.39
Carrot	$ 1.06	$ 0.94	$ 0.96	$ 0.14	$ 1.06	$ 0.57
Turnip	$ 1.05	$ 0.60	$ 1.25	$ 0.64	$ 1.36	$ 0.97
Rutabaga	$ 0.91	$ 0.55	$ 1.16	$ 0.85	$ 1.34	$ 1.07
Celeriac	$ 1.42	$ 0.69	$ 1.85	$ 1.42	$ 1.76	$ 1.69
Potato	$ 1.35	$ 1.33	$ 1.05	$ 0.16	$ 1.07	$ 0.97
Parsnip	$ 1.39	$ 1.34	$ 1.66	$ 0.62	$ 1.60	$ 1.14
Radish	$ 1.40	$ 1.40	$ 1.45	$ 1.47	$ 1.81	$ 1.82

Table 2 - Summary of normal mean and weighted mean unit pricing by crop, 2012-2014.

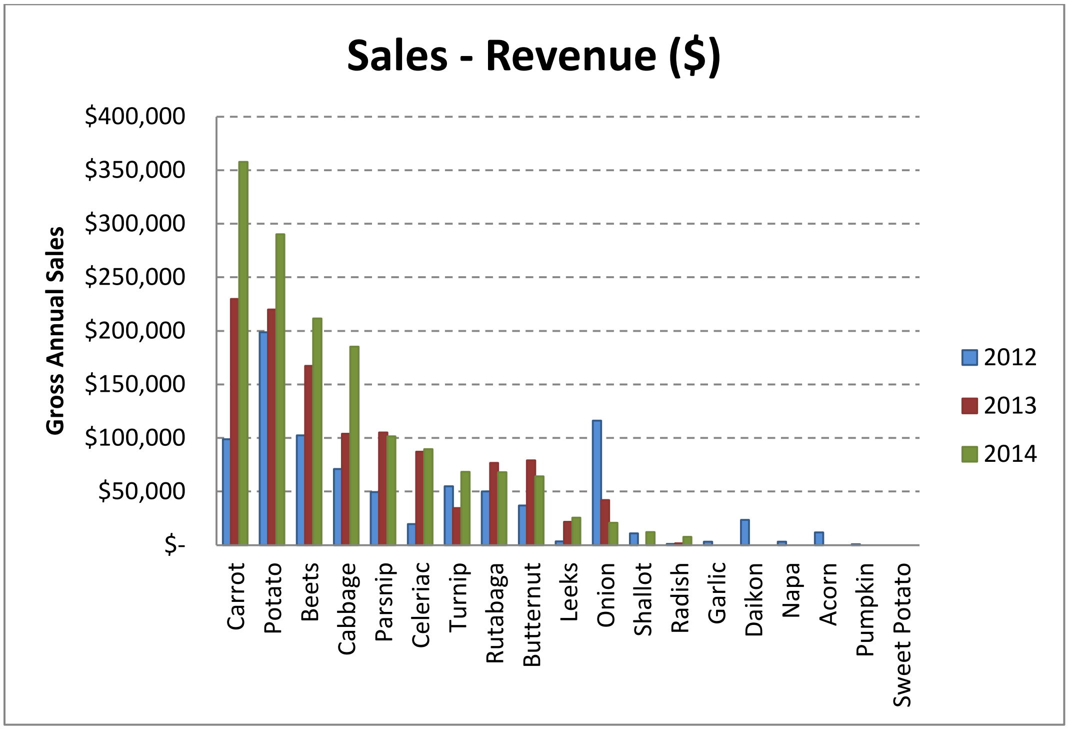


Figure 1 - Sales Revenue by crop and year, 2012-2014. Sorted by 2014 sales, descending.

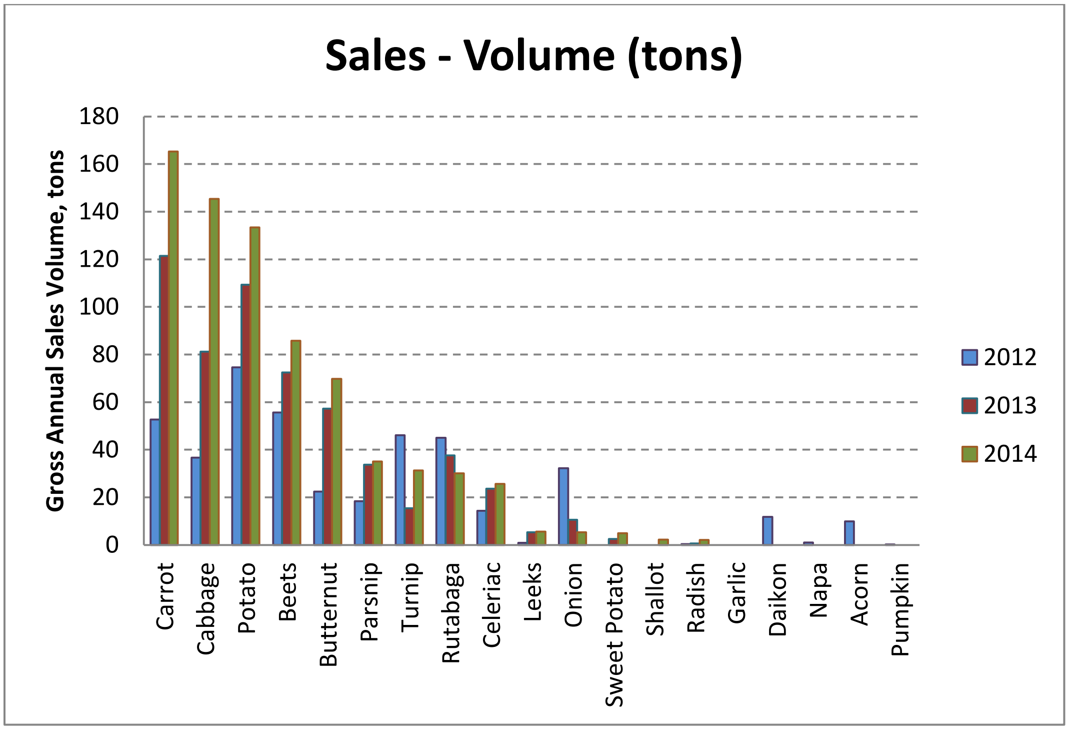


Figure 2 - Sales Volume by crop and year, 2012-2014. Sorted by 2014 volume, descending.

Results

Winter crop storage facilities are best thought of as "hotels", not "hospitals." Damaged or injured crops going into storage will not get better in storage, and tend to get worse. The 2012 and 2013 growing seasons, in particular, were challenging due to high rainfall early spring and late fall and lack of rain at other times. Growers worried about flooded crops one week and needing to irrigate them the next. Poor germination conditions in the spring of 2012 led to poor yields of several crops.. Successive cold nights in early fall led to crop damage via chilling injury in storage squashes. Those that were harvested were prone to storage loss due to tissue damage. Given the challenging growing season, several of our partner farms had a lower than normal storage volume and were eager to move the product early in the storage period to avoid loss in storage due to poor quality crops going into storage. In fact, one planned partner farm who specializes in winter squash had such a poor crop this year that we jointly agreed monitoring this year would be meaningless; his crop was sold out before Thanksgiving. However, the conditions in 2012 favored onion production due to the timing of rainfall and good field drying conditions during harvest.

Better growing conditions in 2014 combined with growth in production due in part to greater confidence in winter storage led to higher sales of stored crops. that year. A general trend toward more aggressive harvest culling - sorting out damaged product prior to storage – was also reported, and this likely improved longevity of the remaining crops in storage and thus helped improve sales as well. Growers also noted several instances of how their monitoring systems allowed them to:

a. push storage conditions closer to optimal conditions,
b. become aware of and respond to freezing danger due to changes in ambient outside conditions, and
c. become aware of and respond to mechanical failure in the refrigeration and storage systems.

Growers credit the monitoring system with helping to reduce cull rate during storage and increase their confidence in storing crops. As one grower noted, “With this system, I obsess more and worry less.”

Another grower noted, “Sub-zero outside temps affected the temperature in our potato cooler, bringing temp down in cooler below freezing. Sensors alerted us to this and we bumped up cooler temperature when faced with this situation. Maybe 5% freeze injury on potatoes that could have been a lot worse without monitoring data. Since our potato cooler is the most exposed to outside temp fluctuations of all of our coolers, we will be adding foam board insulation to the outside of the cooler to help buffer temp fluctuations.”

One of the unique benefits of these monitoring systems is the ability of growers to log and access temperature and humidity data on 5 minute intervals, using their smart phones. Prior to this project, the farms would typically check a thermostat or thermometer reading in their storage compartments once a day. The increased frequency of data access allowed growers to obtain information they wouldn’t otherwise. One example is when one grower saw a 5 degree F temperature rise every 6 hours in a potato storage room. It was so regular it had to be something mechanical, something timed. Upon investigation it was determined to be a problem with a defrost heater on an evaporator which had been programmed to come on every 6 hours, whether needed or not. Given the relatively high storage temperature of potatoes the defrost heater was not actually needed. So the timer was disabled, resulting in a much more consistent storage temperature, and lower electricity consumption since the heater was no longer running every 6 hours.

Another instance of how the monitoring systems helped spot mechanical problems had to do with a slowly increasing temperature in one storage room. The room had been filled with crops and then closed, with a stable storage temperature for nearly a month. The gradual increase in temperature pointed to a potential problem with the refrigeration unit. The grower called a service technician who then identified a slow refrigerant leak that was easily fixed, preventing a larger problem and perhaps significant crop loss later in storage. It is unlikely this problem would have been spotted if storage temperature data was not easily available for the grower to review.

The partnership between UVM Extension and Efficiency Vermont enabled extended technical assistance with regard to reducing electicity used for crop storage. Sixty-six energy efficiency measures were implemented at 5 farms, saving a total of 40,269 kWh of electricity and $5,800 annually. “Working with UVM Extension on this project enabled Efficiency Vermont staff to have conversations with vegetable growers that never would have happened otherwise,” notes J.J. Vandette, agricultural planning manager at Efficiency Vermont, “Extension brings a lot of value to these farmers and we were fortunate enough to leverage these existing relationships to get in the door and to talk about energy efficiency. Efficiency

Vermont staff learned a lot about the specific storage conditions that these farmers require—and about how energy efficiency can work in parallel with their core business."

An additional 150,000 kWh ($20,000) of annual electricity savings opportunities have been identified, and Efficiency Vermont staff are still actively engaged with 5 vegetable growers to realize these additional savings.

Outreach and Education

This project was highlighted in the 2013 Vermont Farm to Plate Annual Report, and in a series of educational workshops funded by USDA's Northeast SARE Partnership Grant Program. These workshop served as a primary outreach and education mechanism allowing us to share initial findings from the monitoring and storage research project with ~300 farmers via workshops, webinars and direct consults. Workshop evaluations indicated that 37% of attendees planned on behavioral and/or operational changes in their post-harvest storage practices based on the workshop content.

Callahan also presented at the New England Fruit and Vegetable Conference in Manchester, NH in December 2013 on post-harvest storage and included monitoring. The audience included approximately 325 farmers and technical service providers. Additional presentations on the project and its outcomes included 2015 Vermont Vegetable and Berry Growers Assn. and Northeast Organic Farming Assn. of Vermont winter meetings. Information from this project has also been extended to other areas in the region including other New England states and the Atlantic Provinces of Canada. An episode of the Burlington, Vermont WCA television station program 'Across the Fence' was dedicated to the project.

Website analytics indicate 13,941 page views (6,218 unique) averaging approximately 2 minutes each by people accessing information related to post harvest storage via the UVM Extension Ag Engineering Blog and its Crop Storage Resources Page during this project period. A page specific to this project and its results has been added to this website to enable growers to easily find and install a monitoring system.

Lastly, the project received national press coverage via 150 print and broadcast media outlets as a result of local Associated Press reporting and distribution. An example of this coverage as printed in the Vermont press is provided in the appendix.

Project Goals and Status

Goal	Performance Measure	Expected Outcome	Accomplishments
1. Increase Winter Storage Monitoring and Control Capacity	Number of farms installing improved monitoring and control systems; cubic feet of storage space and equivalent tons of storage capacity affected.	10 vegetable farms install equipment and gain the ability to 1) monitor the actual temperature and humidity in storage, and 2) maintain optimal storage conditions for their crops.	9 site installations completed with temperature and humidity monitoring and improved control based on automated reporting of conditions. 2 food hubs installations were also completed to allow for improved monitoring of shared storage spaces.
2. Increase Winter Sales of Local Produce	Gross income from sales of stored produce from December through April, with year to year comparisons.	10 vegetable farms increase sales of storage vegetable by an average of 50% over the previous 2 years, for an aggregate increase of $300,000 in gross income.	9 farms increased sales volume by 76% over two years and revenue by 75% in the same period. Aggregate revenue growth over two years was $645,693 (average of $35,871 per farm per year).
3. Decrease Normalized Energy Consumption in Winter Storage	Kilowatt-hours of electrical energy used in cold storage divided by the overall amount of produce stored in that period (may be estimated).	10 vegetable farms decrease the normalized energy consumption (kWh/ton-day) by 20% compared to the previous 2 years of electricity use.	66 energy efficiency measures were implemented at 5 farms saving a total of 40,269 kWh of electricity and $5,800 annually.
4. Improve Cold Storage Knowledge Among Producers and Processors	Test of participant knowledge through instruments of learning (pre and post); number of print, web-based and face-to-face educational contacts.	At least 500 growers gain access to information they can apply to improve vegetable storage conditions on their farm; 100 growers make an improvement to their storage facilities and/or practices.	Over 400 VT and New England growers were introduced to remote monitoring methodologies and equipment through workshop presentations, webinars, and one-on-one consultations. Over 6,000 unique visits to web-based pages with storage information.

Project Financial Summary

The bulk of expenditures were related to the purchase of equipment to build the monitoring networks at each site. A summary of expenditures is provided below.

Category	Budget / Award	Expended	Unused Balance
Construction			
Equipment	$38,000.00	$32,285.62	$5,714.38
Materials			
Other Labor/Equipment			
Travel/Lodging	$2,000.00	$1,793.98	$206.02
Total	**$40,000.00**	**$34,079.60**	**$5,920.40**

The team was able to find a monitoring system at a lower price than we had budgeted which resulted in a lower overall expenditure on equipment. The funds provided by the WLSPG grant were critical to testing this new concept in the field and providing the technical support required to overcome technical challenges associated with early adoption. The support of the WLEF is greatly appreciated by the project leaders and the participating farmers. In the words of one farmer, “Great to be a Vermont farmer with access to all the info and monitoring items/ideas you folks provide! Thanks for all that you do, we are more profitable because of it!”

SCHEDULE STATUS

Scope Item	**Original Schedule**	**Status**	**Notes**
Recruit participating farms:	March 2013	Complete	
Audit each farm: storage size, layout, usage; crop sales; energy consumption:	April/May 2013	Complete	
Identify equipment needs and storage improvement plan for farms.	June 2013	Complete	
Procure monitoring equipment for farms.	July 2013	Complete	
Install equipment, make storage improvements.	August/September 2013	Complete and Ongoing at 9 sites	**Six (6) additional, unplanned sites anticipated in 2015 with equipment already purchased under the grant.**
Test monitoring and control equipment.	August/September 2013	Complete	
Monitoring, data collection, technical support.	September 2013 to April 2014	Ongoing	**Will continue after project performance period.**
Present initial results to growers at VVBGA, NOFA-VT meetings.	January/February 2014	Complete and Ongoing	**Project results have been incorporated in recurring grower outreach and education programming.**
Develop fact sheets, web pages, hold educational workshop.	February/March 2014	Ongoing	**UVM Extension Ag Engineering Blog Page**
Finalize data collection/analysis.	April/May 2014	Complete	
Final report.	June 2014	Complete	**Aug 26, 2015**

Partner Farms and Locations

The following farms have partnered in this project by hosting a monitoring network, tracking storage details and reporting results to the project investigators.

- Pete Johnson & Isaac Jacobs –Pete's Greens – Craftsbury, VT
- Tony and Joie Lehouillier – Foot Brooke Farm – Johnson, VT
- Andy Jones – Intervale Community Farm – Burlington, VT
- George Gross – Dog River Farm – Berlin, VT
- Mark Fasching and Christa Alexander – Jericho Settler's Farm – Jericho, VT
- Hank Bissell – Lewis Creek Farm – Starksboro, VT
- David Marchant – River Berry Farm – Fairfax, VT
- Joe and Anne Tisbert – Valley Dream Farm – Cambridge, VT
- Paul Harlow and Jon Slason – Harlow Farm – Westminster, VT

We were also able to install monitoring systems at two food hubs.

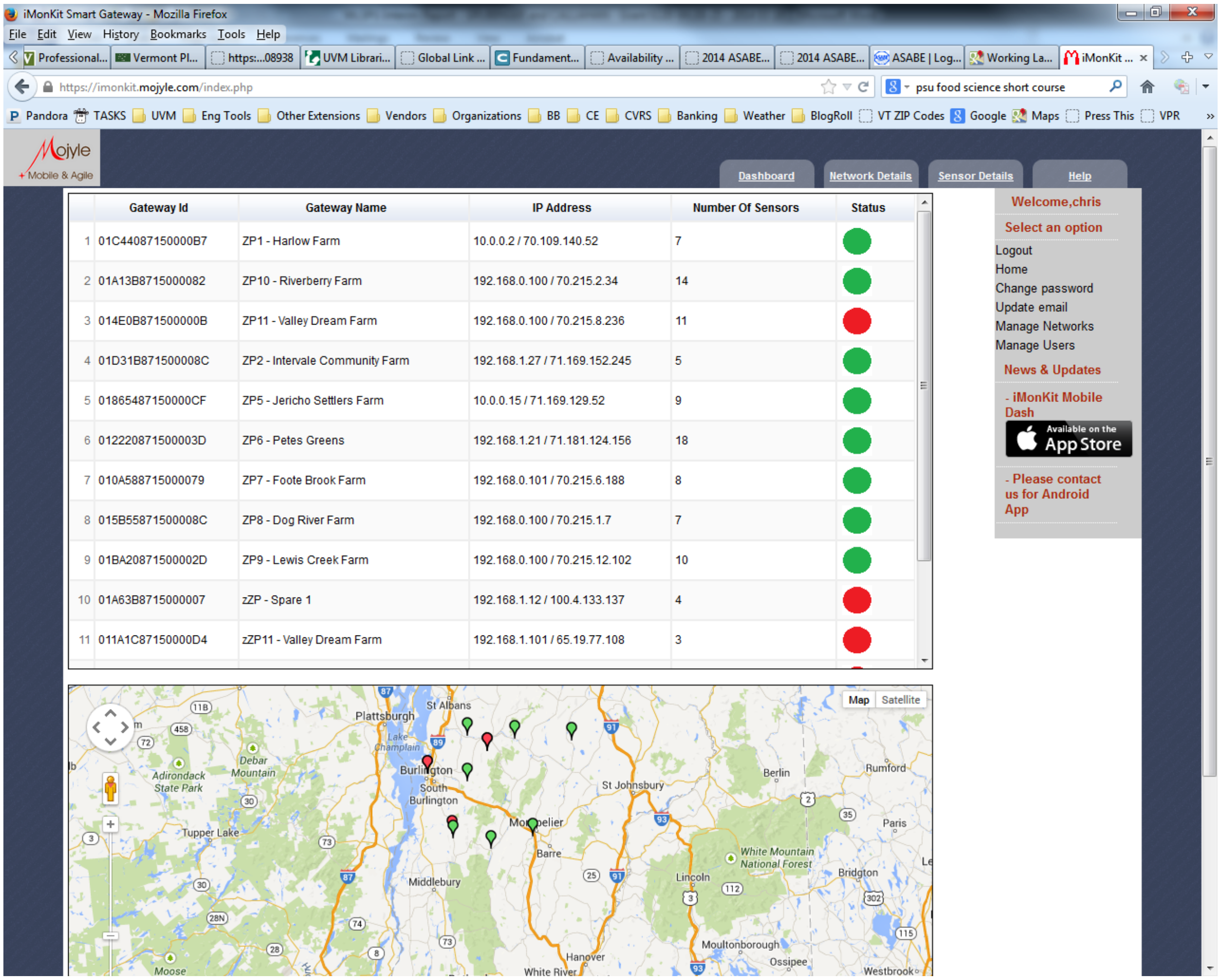
- Mad River Food Hub – Waitsfield, VT
- Vermont Food Venture Center – Hardwick, VT

We anticipate installing monitoring systems at the following locations in 2015 using equipment purchased with WLSPG funds.

- Intervale Food Hub – Burlington, VT
- Luna Blue Farm – S. Royalton, VT
- Burnt Rock Farm – Huntington, VT
- Laughing Child Farm – Pawlet, VT
- True Love Farm – Shaftsbury, VT
- Mighty Food Farm – Pownal, VT

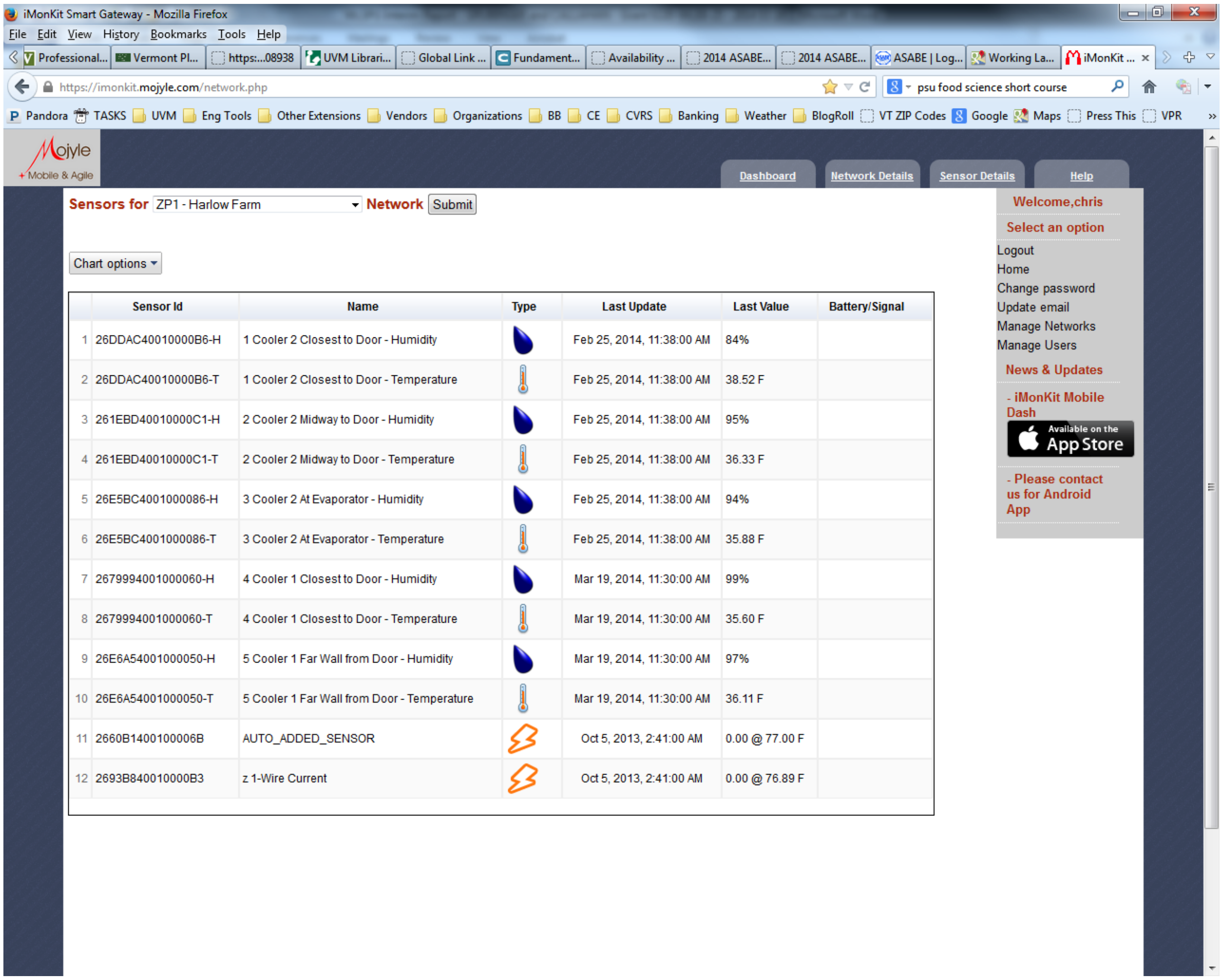
Appendix

APPENDIX A – Screen Shot of Monitoring Dashboard



	Gateway Id	Gateway Name	IP Address	Number Of Sensors	Status
1	01C44087150000B7	ZP1 - Harlow Farm	10.0.0.2 / 70.109.140.52	7	
2	01A13B8715000082	ZP10 - Riverberry Farm	192.168.0.100 / 70.215.2.34	14	
3	014E0B871500000B	ZP11 - Valley Dream Farm	192.168.0.100 / 70.215.8.236	11	
4	01D31B871500008C	ZP2 - Intervale Community Farm	192.168.1.27 / 71.169.152.245	5	
5	0186548715000CF	ZP5 - Jericho Settlers Farm	10.0.0.15 / 71.169.129.52	9	
6	012220871500003D	ZP6 - Petes Greens	192.168.1.21 / 71.181.124.156	18	
7	010A588715000079	ZP7 - Foote Brook Farm	192.168.0.101 / 70.215.6.188	8	
8	015B55871500008C	ZP8 - Dog River Farm	192.168.0.100 / 70.215.1.7	7	
9	01BA20871500002D	ZP9 - Lewis Creek Farm	192.168.0.100 / 70.215.12.102	10	
10	01A63B8715000007	zZP - Spare 1	192.168.1.12 / 100.4.133.137	4	
11	011A1C87150000D4	zZP11 - Valley Dream Farm	192.168.1.101 / 65.19.77.108	3	

APPENDIX B – Example Farm Dash Board (Harlow Farm) Showing Each Sensor's Status



	Sensor Id	Name	Type	Last Update	Last Value	Battery/Signal
1	26DDAC40010000B6-H	1 Cooler 2 Closest to Door - Humidity		Feb 25, 2014, 11:38:00 AM	84%	
2	26DDAC40010000B6-T	1 Cooler 2 Closest to Door - Temperature		Feb 25, 2014, 11:38:00 AM	38.52 F	
3	261EBD40010000C1-H	2 Cooler 2 Midway to Door - Humidity		Feb 25, 2014, 11:38:00 AM	95%	
4	261EBD40010000C1-T	2 Cooler 2 Midway to Door - Temperature		Feb 25, 2014, 11:38:00 AM	36.33 F	
5	26E5BC4001000086-H	3 Cooler 2 At Evaporator - Humidity		Feb 25, 2014, 11:38:00 AM	94%	
6	26E5BC4001000086-T	3 Cooler 2 At Evaporator - Temperature		Feb 25, 2014, 11:38:00 AM	35.88 F	
7	2679994001000060-H	4 Cooler 1 Closest to Door - Humidity		Mar 19, 2014, 11:30:00 AM	99%	
8	2679994001000060-T	4 Cooler 1 Closest to Door - Temperature		Mar 19, 2014, 11:30:00 AM	35.60 F	
9	26E6A54001000050-H	5 Cooler 1 Far Wall from Door - Humidity		Mar 19, 2014, 11:30:00 AM	97%	
10	26E6A54001000050-T	5 Cooler 1 Far Wall from Door - Temperature		Mar 19, 2014, 11:30:00 AM	36.11 F	
11	2660B1400100006B	AUTO_ADDED_SENSOR		Oct 5, 2013, 2:41:00 AM	0.00 @ 77.00 F	
12	2693B840010000B3	z 1-Wire Current		Oct 5, 2013, 2:41:00 AM	0.00 @ 76.89 F	

APPENDIX C – Summary Data for a Single Sensor (Beet Room at Pete's Greens)

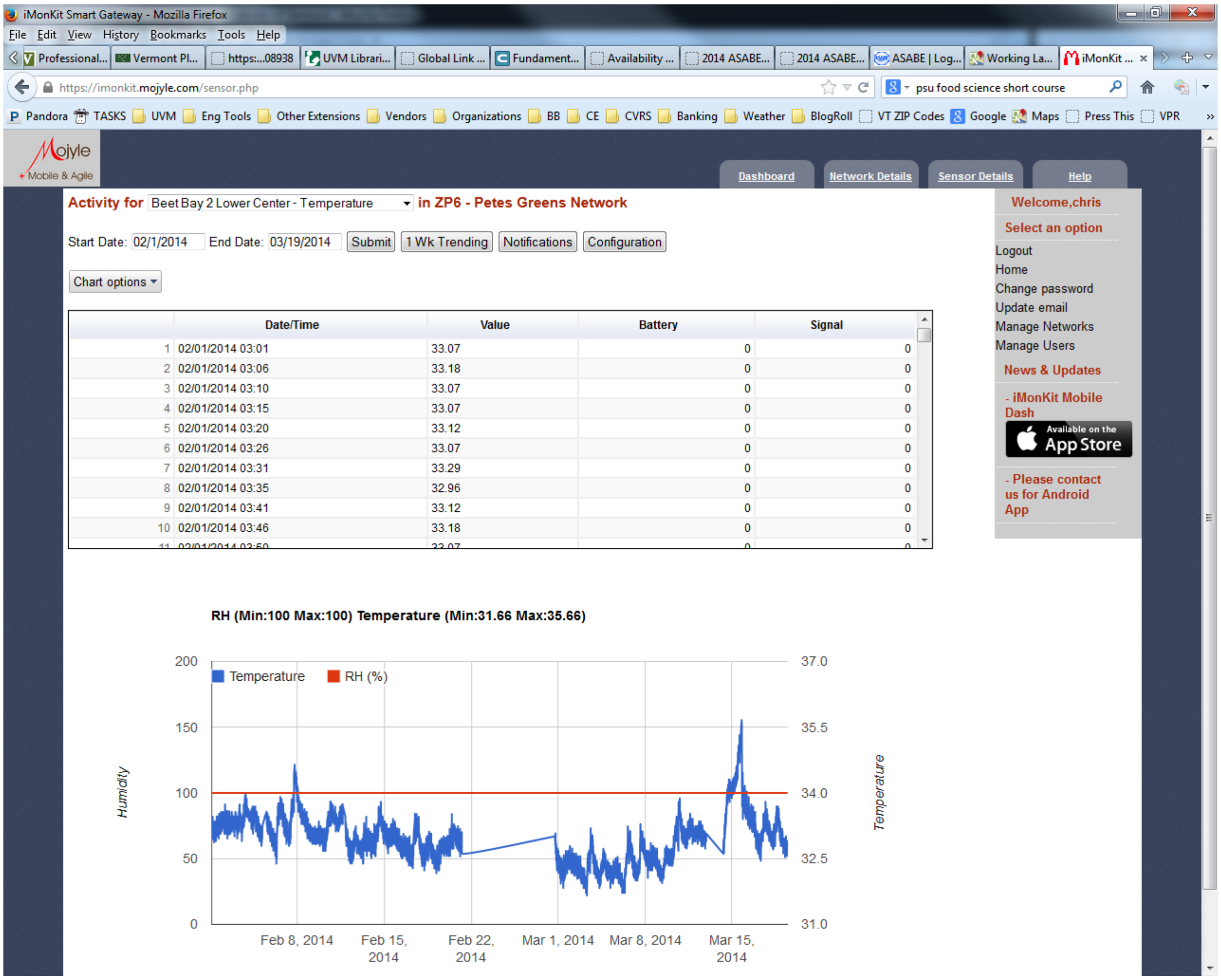


Figure 3 - Beets in storage at Foote Brook Farm in Johnson, VT.

Figure 4 - Bagged carrots in storage, ready for delivery from Dog River Farm in Berlin, VT.

Figure 5 - Chris Callahan and Tony Lehouillier talk about the plan for installing the monitoring system at Foote Brook Farm in Johnson, VT.

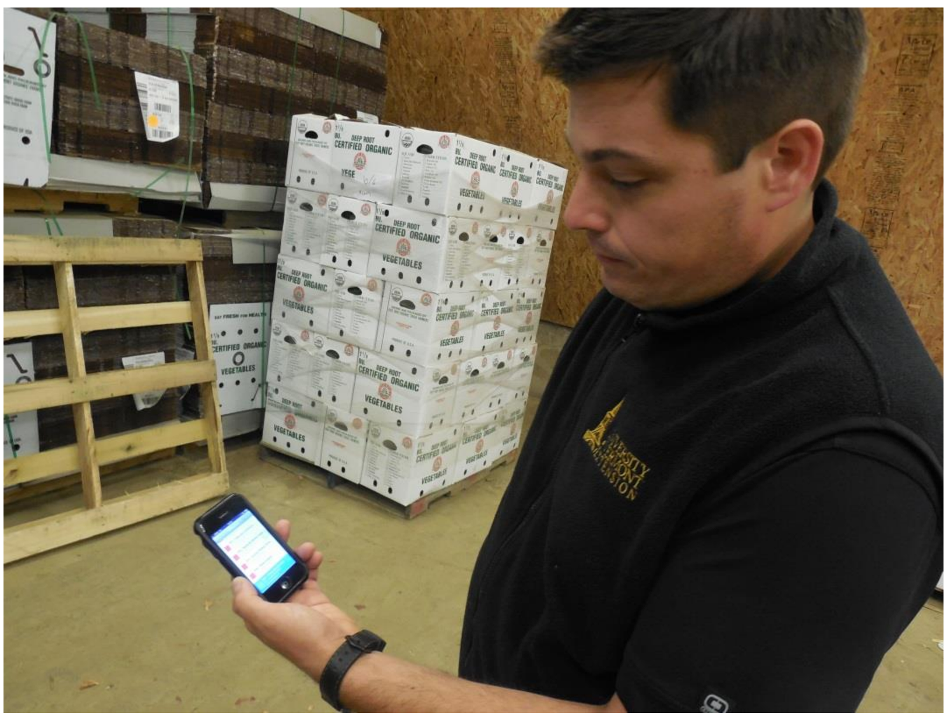


Figure 6 - Chris Callahan demonstrates checking in on the storage room conditions using a smart phone app.

Figure 7 - Chris Callahan sets up the monitoring network at Harlow Farm in Westminster, VT. Top: Wiring the sensor network. Bottom: Checking the sensor operation via the internet.

Figure 8 - Rutabaga in storage at Harlow Farm in Westminster, VT. A temperature / humidity sensor is shown in the upper left corner (yellow box attached to the lighting conduit.)

Figure 9 - A typical network gateway setup, this one at Lewis Creek Farm in Berlin.

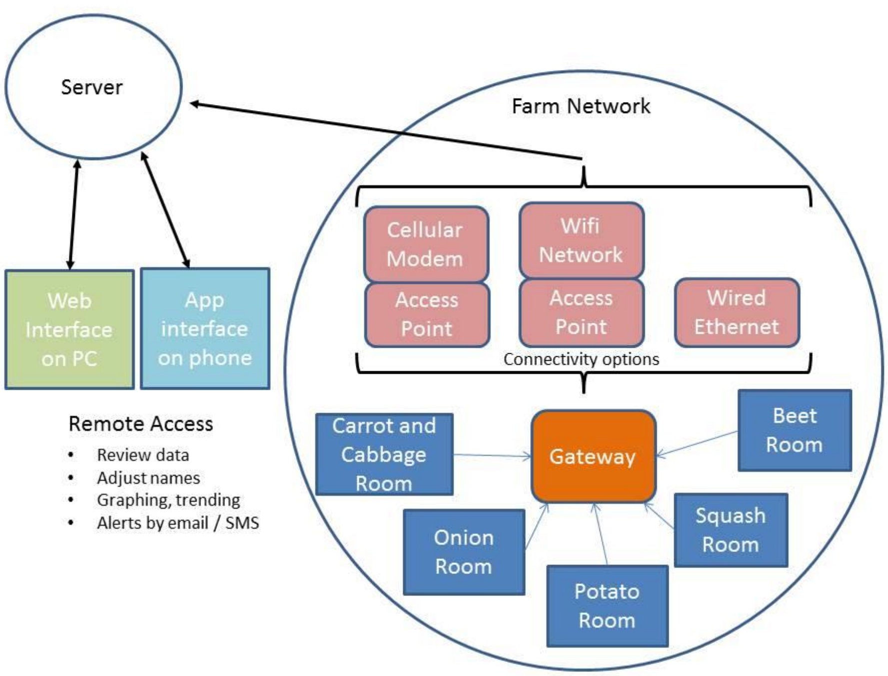


Figure 10 - Schematic of a typical monitoring network.

Vermont Press Coverage of AP Story

Vermont farms monitor storage conditions by cellphone

... Vermont **farm**s monitor storage conditions by cellphone Lisa Rathkethe Associated Press Tim Fishburn, sales manager at...

Rutland Herald - 3/8/2015

Vt. Farmers Monitor Storage With Phones

... Vt. **Farm**ers Monitor Storage With Phones Lisa Rathke Sunday, March 8, 2015 (Published in print: Sunday,...

Valley News - 3/8/2015

Vermont farms monitor storage conditions by cellphone

... Vermont **farm**s monitor storage conditions by cellphone Tim Fishburn, sales manager at Pete's Greens in Craftsbury,...

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Article published Mar 8, 2015

Vermont farms monitor storage conditions by cellphone

By LISA RATHKE
The Associated Press
CRAFTSBURY — Temperature fluctuations can shorten the growing season for farmers, and the worry doesn’t stop when crops are stored inside for winter sales, as a drop or spike can ruin what’s meant for market.

For years, growers would have to walk into coolers or other storage spots to check the temperature and humidity. Now, some small-scale vegetable producers in Vermont who can’t afford high-tech refrigeration are gaining access to remote monitoring systems that keep cold storage in check, provide updates by cellphone and ease their worries.

The University of Vermont Extension Service’s test project installed remote thermostat technology to check conditions at nine farms.

Since last winter, the system reduced the rates of vegetables that needed to be thrown out or culled by 30 to 50 percent — adding an average of $10,000 in revenue to each farm, university officials said.

The growers like it because they physically check their storage less often and, thanks to updates from their cellphones, are able to detect and quickly fix any problems.

Though it’s only being tested in the Northeast, the system could work in any region of the U.S. or facility where careful attention to temperature and humidity is critical. What’s needed is a good Internet connection — which isn’t always available in rural areas.

“The fact that there’s something in there all the time checking in on it, letting us know what’s going on is extremely helpful,” says Pete Johnson, owner of Pete’s Greens, an organic vegetable and community-supported agriculture farm in northern Vermont.

More than two years ago, his business lost 20 tons of potatoes, worth about $25,000, when the temperature in its cold storage room dropped. Since installing the remote sensors, the farm is losing far less produce and storing it longer.

“Some larger farmers may be able to absorb storage losses or produce losses due to inadequate storage because they’re making it up in volume. But these guys are not able to absorb that loss due to volume,” said Chris Gunter, vegetable production specialist for the North Carolina State University Cooperative Extension.

He added that he hadn’t heard of growers using this type of technology, but that it would be useful, especially for those who don’t live on their farmland.

Remote monitoring already is available nationally to large-scale producers and distribution centers at a cost of more than $10,000. The university’s model runs $500 for the equipment and an estimated $500 to install, according to UVM agricultural engineer Chris Callahan.

UVM bridged the Internet connectivity problem with installing cellular modems where needed.

“The neat thing was that it gave growers real-time visibility into their storage rooms and they didn’t need to be there,” he said. “And the other thing it did ... every five minutes getting a data point, you start to realize things you don’t see when you look at the conditions once a day.”

In Maine, most small farmers monitor their cold storage and refrigeration “by the seat of their pants,” said Mark Hutton, vegetable specialist with the state’s cooperative extension. But the UVM model brings existing technology down to a size that’s useable — and useful — for Northeast growers, who tend to have smaller storage units than growers in other parts of the country.

The system has boosted growers’ confidence in their winter crop storage, and most who participated in the UVM project plan to expand storage by at least 50 percent, Callahan said.

Andy Jones of the Intervale Community Farm in Burlington said storage investments and adding the sensors has “allowed us to store things for much longer” and the quality of its raw vegetables like cabbage has improved.

This winter, he has gone weeks without getting any text-message alerts, until something like a cold snap produces a number of alerts until an adjustment is made.

“Now I would say I’m worried less and I’m obsessing less,” he said.