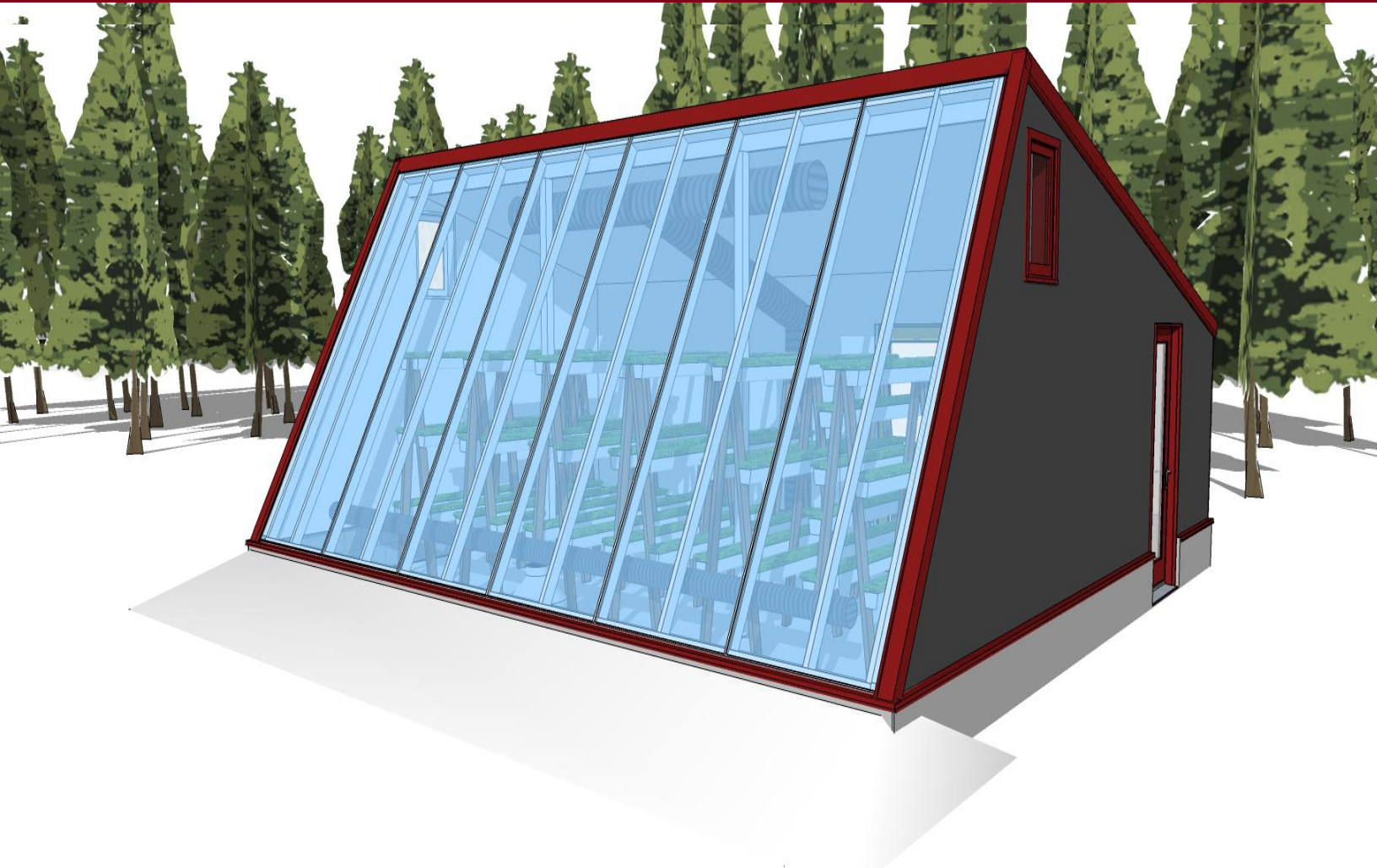


2020 | By: Zoë Masterpole, Research Assistant



Nonprofit Use of Deep Winter Greenhouses: Minnesota Case Studies



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Nonprofit Use of Deep Winter Greenhouses: Minnesota Case Studies

January 2020 | By: Zoë Masterpole, Research Assistant

This is a co-publication of the University of Minnesota's Center for Urban and Regional Affairs (CURA), Southwest Regional Sustainable Development Partnership, and MNYou Youth Garden.

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The Southwest Regional Sustainable Development Partnership brings together local talent and resources with University of Minnesota knowledge to drive sustainability in agriculture and food systems, tourism and resilient communities, natural resources and clean energy. The Partnerships are part of University of Minnesota Extension.

CURA strives to be a nationally recognized model for university-community engagement and is founded on the belief that partnership between the University and the community is mutually beneficial.

MNYou Youth Gardens increase access to fresh vegetables in the Willmar area through gardening with minority youth and offering a community-supported agriculture (CSA) program that donates shares to low-income families.

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Partners

Southwest Regional Sustainable Development Partnership

The Southwest Regional Sustainable Development Partnership (SWRSDP) works toward region-wide sustainability in southwest Minnesota. University of Minnesota Extension's Regional Sustainable Development Partnerships bring together community and University resources to support local projects. Community members and University faculty and staff work hand-in-hand to identify and nurture locally grown projects. SWRSDP is committed to bringing together people with diverse backgrounds and perspectives to jointly work on sustainability issues. For more information, see rsdp.umn.edu.

MNYou Youth Garden

MNYou Youth Gardens increase access to fresh vegetables in the Willmar area through gardening with minority youth and offering a community-supported agriculture (CSA) program that donates shares to low-income families. They are interested in building a Deep Winter Greenhouse (DWG) in downtown Willmar to house their training program for new immigrants to the Willmar area to learn the basics of growing food in Minnesota. The training cohorts will then have the resources to start neighborhood gardens to help make healthy food accessible to all community members.

Acknowledgment

This report would not have been possible without the support of the aforementioned partners, in addition to the wonderful community of Deep Winter Greenhouse producers, managers, and supporters. The DWG and local food advocates in Minnesota are strongly guided by their passion and willingness to share their knowledge with others in the pursuit of a more sustainable world. I would like to thank everyone who donated their time in the process of making this report and, more importantly, in the creation of this movement and technology. They helped immensely in gaining an understanding and appreciation for what the deep winter technology can and will do for Minnesotans and their local food systems. This report hopes to honor all of the work they have put into this movement and inspire more people to join.

Background

Design

In order to grow crops all winter long, pioneering farmers throughout the state of Minnesota developed a greenhouse that enables the growth of cold-weather crops while using minimal inputs of external heat and lighting. This greenhouse has been termed a Deep Winter Greenhouse. What specifically makes a Deep Winter Greenhouse (DWG) is the fact that it uses a heat storage system to capture solar heat for later use. DWGs often have a steeply-sloped south-facing glazing wall, allowing the capture of solar energy even during the shortest days of winter. This energy is usually stored in an underground rock bed or soil pit with insulated walls and some sort of ventilation that draws the solar-heated air that has risen to the ceiling, into the underground materials. This stored heat dissipates into the planting area throughout the night. This report will use DWG and greenhouse interchangeably. Non-deep winter greenhouses will be identified as conventional greenhouses. Reports, books, and other resources cited in this text are listed and linked in the appendix.

Different DWG models have existed and evolved as the concept has grown over the past decade. More information on the design can be found through the University of Minnesota Extension, available at z.umn.edu/rsdpDWG, and from the book, *The Northlands Winter Greenhouse Manual* by Carol Ford and Chuck Waibel.

Role

Minnesota, one of the top five agricultural exporting states in the United States, imports a large majority of its food¹. Additionally, the current large-scale food system relies heavily on fossil fuels in both production and transport. DWGs fit well into local food systems that hope to combat those issues by producing healthy food locally and increasing access to fresh foods in the winter, while doing so with limited inputs.

Production

These are the three seasons for growing in a DWG according to *The Northlands Winter Greenhouse Manual*: diminishment, solstice, and expansion. These are based on the amount of daylight available.

Diminishment			Solstice		Expansion		
Sep	Oct	Nov	Dec	Jan	Feb	March	April

¹ USDA- Economic Research Service. Retrieved from <https://www.ers.usda.gov/faqs/>

Each greenhouse varies slightly in what they grow and when they start and stop growing. While reading through the case studies, you will find different techniques that are used to extend the seasons or use the DWG during the off-season. Those who have been using their greenhouses for many years have cited a need to push back the start of their DWG season to early or mid-October because of the high temperatures they are experiencing later in the year.

In addition to food production, the highlighted DWGs in this report are used for research, workforce development, and a wide array of educational uses. The benefit to the aforementioned DWG seasons is that they overlap with the school year more than conventional greenhouses or farm-to-school programs, allowing DWGs to better integrate into school-based educational institutions.

Financial Considerations

The use of DWGs as a source of income for the financial sustainability of non-profits is not extensively covered in these case studies. A 2018 study, *Winter Greenhouse Enterprise Analysis* by Ryan Pesch, found that the average operating revenue (gross revenue minus variable costs like fuel and seed) for those using DWGs for production was \$1,990. The study also found that average construction costs for DWGs was \$33 per square foot of space. The average variable costs were found to be \$906. Estimates of the construction costs, start-up costs, and production value for the greenhouses represented in this report can be found in the individual case studies.

Selection of cases

The cases presented in this report were selected based on their DWG having one of the following characteristics:

- It is used in the pursuit of a non-profit organization's mission.
- It is used for educational purposes.
- It is located in an urban setting.
- It is used for personal pursuits outside of income.

Methodology

Participants in this research were contacted over email and through telephone calls. Telephone interviews were set up, lasting around 30-60 minutes each. These interviews were informal and tried to cover the following topics in as much detail as the respondent could provide:

- Background information on why the DWG was built, the purpose it was intended to serve, and how it was funded
- Zoning considerations and construction issues that arose
- The current usage of the space (layout, what is grown, and who uses it)

- Management of the greenhouse
- Things interviewees would have done differently if they were to do it again
- Future usage of the greenhouse

In cases where the respondent was unsure of the answer, additional interviews and research were completed. Many interviewees extended invitations to visit their greenhouse. This offer was taken up by the project team in the case of one greenhouse with a longer-than-usual growing season compared to the others, located in New London (pg. 24).

Results

As with any new innovative idea, the wave of excitement surrounding DWGs is hard to ignore. It is exactly that enthusiasm for the technology that has led to many DWGs being built around the state of Minnesota and the continued work that has gone into the model since their conception. These case studies give a look into the process that occurs for nonprofits throughout the realization of this idea. Prior to breaking ground on this exciting new technology, the planning process may be slow and require a lot of leg work. These cases show that the more that is planned, the more likely things will go smoothly with construction and throughout continued usage.

Process

The necessary steps involved before even building a greenhouse are as follows:

1. Define the purpose
2. Determine who will be involved and in what capacity
3. Find a site that is suitable for the DWG
4. Define who will be involved in the construction, maintenance, and operations of the greenhouse
5. Locate where the produce that is grown will go

Once all of these have been figured out, the ground should be broken. This path is followed throughout each case study. If the case study did not follow that path, it will be noted. This is in hopes of relaying the importance of all the steps that need to be considered before construction even starts.

Purpose

First and foremost, an individual or organization seeking to build a DWG needs to ask themselves, what purpose do we want this greenhouse to serve? Why is a passive-solar, winter greenhouse preferred over a conventional greenhouse? Whether as a source of income, educational space, or a source of fresh produce for a school lunch program, there are many ways the model can be used for non-profits. But each of these usages requires different considerations in the design process, construction, and continued management of the greenhouse. The *Cold Climate Green*

House Resource publication labels this step as “defining priorities.” More information on how these priorities will influence the design of the greenhouse itself, as well as planting schedules and management choices, can be found in that report.

Management

The next question after the purpose has been defined is who will be involved in the process of fulfilling that purpose and what will their role consist of? As a few of the case studies show, the more partners involved in the design and construction, the harder or longer the process may be. But there are many ways to have successful partnerships, like in the case of schools that have different student groups run the greenhouse during different parts of the year.

Interviewees emphasized that a DWG must be run, or volunteers must be managed, by someone who is paid or compensated. The DWGs using volunteer-run models, or models that add DWG operation onto already overworked staff members, ended up being underutilized or experiencing crop failure more frequently.

Site Selection

After defining the purpose that the greenhouse will serve and who will be involved, those decisions can guide the placement of the greenhouse. Site selection needs to take into account the many considerations laid out by Ford and Waibel, like solar position, water source and other utility access, and proximity to other buildings. Additional considerations discovered during this research include looking into who owns the land, what the land is zoned, what types of structures and activities are allowed in that type of zoning, accessibility for those who will manage and use the greenhouse, and requirements of insurance companies.

As laid out in the case studies, site selection has played a major role in many of the issues experienced by interviewees. The issues are extremely site- and city-specific but give a good idea of the due diligence that needs to occur when picking out a site. Some sites had to raise the foundations of the greenhouse because of water issues (drainage, high water table, etc.), which increased construction costs. Others faced restrictions in their ability to sell produce because of the zoning designation of the parcel of land. Others had to pay the prevailing wage and have an ADA accessible bathroom to comply with landowner requirements. Having the site surveyed and understanding the city code that governs the plot will save a lot of time and prevent future headache. At the same time, many of the greenhouses in the case studies are built next to or near existing structures and/or in municipalities with little regulation over zoning, therefore they experienced minimal or no issues.

Construction

Once a site has been selected, the next step is to dive into how to construct the DWG. Some design considerations are linked to the purpose, like how big a space is needed and the type of supplemental heating that will be used.

Management of the construction process will depend on who will primarily be constructing the greenhouse – hired labor or volunteers. Volunteers can be used to help build the structure, as is seen in many of the case studies, but may make it harder to get final approval on the integrity of the structure if the municipality requires that. It is important to check with the local government to understand their requirements and to specify which components, if any, volunteers can help construct.

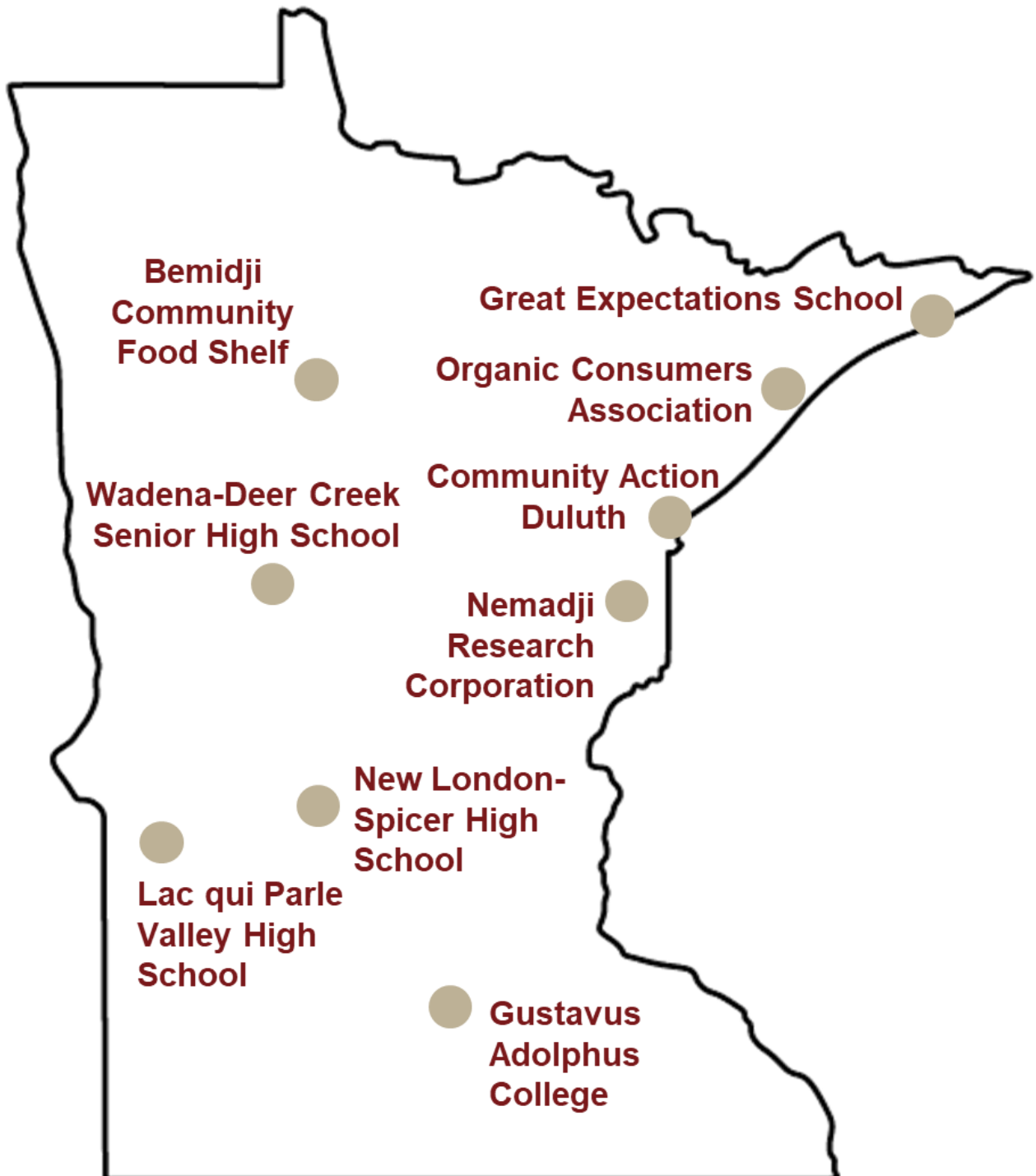
Students can also be used to build the structure but are more restricted by time. With the ability to work only for certain class periods, there is a lot of turnover while completing a task. Having someone in charge of the management process when volunteers or students are used is vital, as that individual is able to manage workflow considerations during the construction process.

Future Considerations

During the collection of these case studies, ideas about the future of DWGs and their usage were discussed. A few ideas came up multiple times and are worth exploring more, especially as they relate to educational and non-profit usage. One of these ideas is the compilation of a DWG-specific curriculum. This came up when discussing reasons why some school-based DWG are not used to their fullest potential, with the need for lesson plans being a barrier to that. Teachers often have to teach to state standards and the creation of additional lesson plans is more than most have time for. Pre-curated lesson plans could be developed to address DWG-specific topics like the thermodynamics of heat capture, geometric calculations around sun-exposure, and the growing needs of plants.

Another idea is identifying ways that cities and counties can adapt their zoning ordinances to be more agreeable to this technology. The city of Milwaukee has a written code that is very amenable to urban food systems and allows for DWGs to be built on plots of lands without treating them like principle structures that demand safety requirements on par with homes. More information is needed on how citizens and organizations can self-advocate for more DWG-friendly zoning, including draft wording that helps place DWGs within existing codes.

Case Study Locations



Case Studies

Non-Profit

Private

Bemidji Food
Shelf
Pg.13

Community
Action Duluth
Pg. 15

Organic
Consumers
Association
Pg. 17

Nemadji
Research
Corporation
Pg. 19

School-Based

Elementary/
Middle School

High School

College

Great
Expectations
School
Pg. 21

Lac qui
Parle
Valley
Pg. 23

New
London-
Spicer
Pg. 25

Wadena-
Deer
Creek
Pg.27

Gustavus
Adolphus
College
Pg.29

	Bemidji Community Food Shelf	Community Action Duluth	Organic consumers Association	Nemadji Research Corporation	Great Expectations School	Lac qui Parle Valley High School	New London-Spicer High School	Wadena-Deer Creek High School	Gustavus Adolphus College
Location	Bemidji, MN	Duluth, MN	Finland, MN	Bruno, MN	Grand Marais, MN	Madison, MN	New London, MN	Madison, MN	St. Peter, MN
Dimensions	384 ft ² (24 ft by 16 ft)	384 ft ² (24 ft by 16 ft)	384 ft ² (24 ft by 16 ft)	512 ft ² (32 ft by 16 ft)	300 ft ² (20 ft by 15 ft)	800 ft ² (40 ft by 20 ft)	900 ft ² (30 ft by 30 ft)	768 ft ² (24 ft by 32 ft)	1050 ft ² (15 ft by 70 ft)
Purpose	Grows food for the food shelf. Also used for education and community service opportunities.	Production, workforce development, houses hydroponics system.	Production, research, and education.	Houses an aquaponics system with bluegills. Food grown goes to a free lunch program.	Used for miscellaneous purposes for the school. Hope to use it for production and educational usage.	Production, some educational usage through extracurricular, CSA, possible fundraising.	Educational, food production, fundraising.	Production, some educational usage.	Houses industrial composter, educational usage, food production for dining services.
Year built	2017	Winter of 2018-19	Winter of 2016-17	2003	2005	2011- 2012	2014	2013	2014
Funding	\$30,000 grant from the University of Minnesota.	~\$300,000 funded by multiple organizations.	\$65,000 funded through University of Minnesota grant.	Mostly privately funded supplemented by a grant from the University of Minnesota.	\$10,000, funded by the Northland Foundation.	~\$30,000+ funded by grants and the school district.	\$30,000 in total with grants covering \$26,000.	\$35,000 in total with three grants covering ~\$30,000.	~\$300,000 for the combined composter, shed, and greenhouse kit. Funded by private donation.
Zoning	Industrially zoned	Originally commercial, now agricultural	Residentially zoned	N/A	N/A	N/A	N/A	N/A	N/A
Growing season	October—May	October—May	Year round	Year round	October—May	November 1—March	October 1—end of May	Year round	October-Dec, Feb-May
Heat sink	4 ft insulated foundation filled with river rock.	Cement foundation and water storage system.	4 ft insulated foundation filled with crushed river rock.	8 inches of concrete and 12 inches of sand as the foundation, and back brick wall.	Insulated foundation filled with gravel.	Insulated foundation filled with river rock.	5 ft insulated foundation filled with river rock.	8 ft insulated foundation filled with pea rock and sand.	Air source heating panels that move heat into sand underneath the growing beds.
Supplemental heat source	Electric	Electric	Electric	Electric	None	Electric	Electric and geothermal	Propane	The industrial composter, electric heater, and electric heating pads.

Bemidji Community Food Shelf

Located in Bemidji, MN

Function

The Bemidji Community Food Shelf is one of the largest non-profits in Bemidji and one of the largest food shelves in the state. Their DWG is located on the food shelf farm, immediately south of the food shelf building on the same parcel of land. The greenhouse is used to grow crops that are given away at the food shelf. It also provides community service opportunities for those in the area. This DWG was built as part of a statewide initiative funded by the Regional Sustainable Development Partnerships (RSDP) that constructed five DWGs as 2.0 prototypes.



Management

Their greenhouse is managed by a farm manager, which is a part-time funded position. Additionally, they have a few volunteers with relevant expertise who donate their time weekly to the DWG and farm.

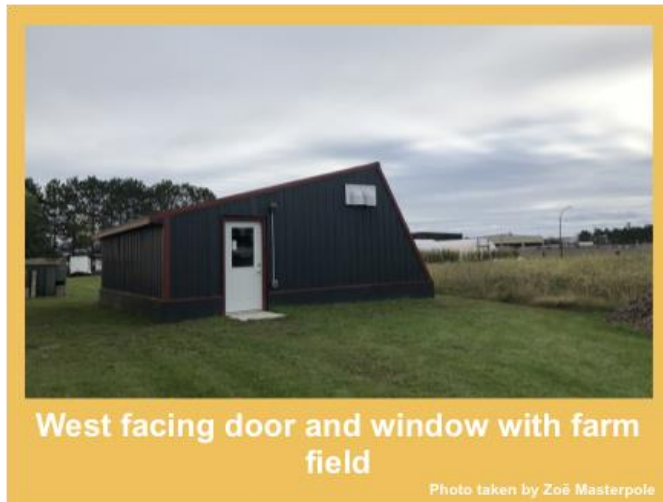
Their management suggestions are that the greenhouse could be managed with just a handful of volunteers if they are willing to come in regularly. They also emphasized the need for one person who should be paid a small amount to organize those volunteers and make sure things get done in a timely manner.

They grow six kinds of micro-greens, radishes, chard, peas, salad greens from the young pea plants, and some herbs. They have had experiences with certain vegetables not being received well by those who frequent the food shelf. They had previously grown beets, but people were not interested in them.

The operating costs for last year (2018-2019) were estimated to be under a thousand dollars. This includes \$60 for the supplemental heater and \$600 for a pallet of growing medium. That same winter was very cold and dark, so the supplemental heater ran the whole winter. They produced a minimal amount of produce this year inside the greenhouse, estimated to be valued under \$200 due to problems with management. This year they are waiting on a grant to grow tomatoes that would turn the building from a 6- or 7-month growing season into a 9- or 10-month growing season, allowing them to start tomatoes even earlier than February. If they can do that, they would be looking at growing produce with a value ranging from \$4,000 to \$5,000.

Construction

The Bemidji Food Shelf worked with a retired contractor who was responsible for building the heat sink. They emphasized the importance of having someone working on the construction who knows what they are doing so they are comfortable dealing with inspectors and other bureaucratic issues that may come up.



The food shelf is located in the industrial park, but it is still within the city limits of Bemidji. This location presented issues during site-selection because it has very few locations with adequate sun. Also, it has a very high water table, which required them to raise the foundation 12 inches. In retrospect, they wish it would have been raised even more, to 24 inches in total. They put in a PVC pipe down to the level of the foundation and there was some moisture

there, causing concern that they could have gone higher. Comparatively, their DWG is not buried as deeply in the ground as others. They put a berm up around the foundation after it was done so there is some earth insulation and they added additional insulation inside. It is important to keep the rock bed dry since it really loses its insulating property when it is wet, which presents their biggest challenge.

They emphasized how great the city of Bemidji was to work with on this project. They submitted the design plans to the city for approval, and the city waived the fee which was multiple hundreds of dollars. They received two inspections: one when they were completing the foundation and the other after the framing was built. The structure was a little different than what the inspectors had seen before, but they were able to talk to Dan Handeen, a researcher at the University of Minnesota College of Design's Center for Sustainable Building Research, who helped explain the construction choices, and they ended up approving the structure.

Future considerations

The exterior is metal, which was a change they made from the prototype design. This is more maintenance-free compared to the exteriors that are made with painted wood. They would highly recommend the metal if possible, as it is easier to take care of.

They have well-water that is tested often. They have access to city water, but it is not preferable for the crops because of the chlorine content and other additives. Additionally, it would be more expensive, even with the use of drip irrigation.

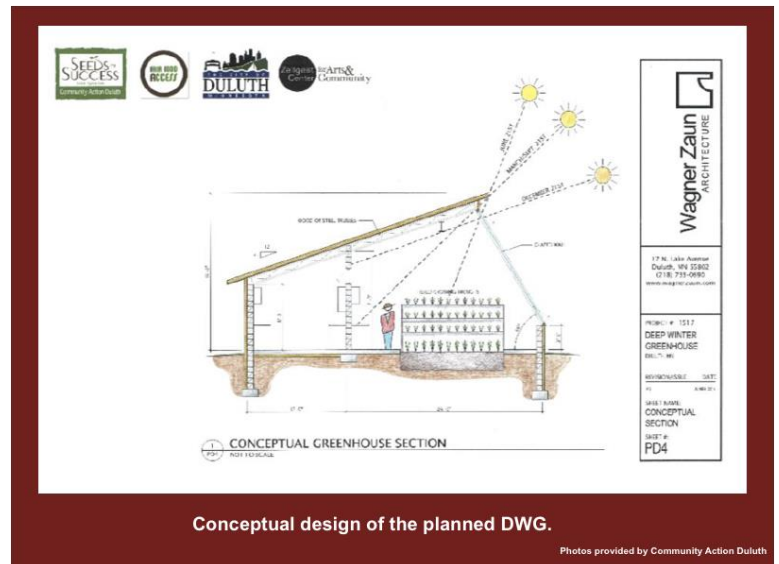
Community Action Duluth

Located in Duluth, MN

Function

The Community Action Duluth (CAD) DWG was built to help increase fresh and healthy food access to a neighborhood that is considered a USDA food desert in Duluth. The fresh vegetables that are grown in the CAD DWG are predominately sold at a farmers market in that community. The revenue from the sales goes back into CAD's programming budget to help the organization become less reliant on grant funding.

They hope to one day use the CAD DWG space for transitional employees who have barriers to finding work. This is normally done through garden plots, but the DWG will allow them to continue that into the winter. They also see the DWG as a community resource for anyone interested in sustainable and innovative community initiatives around food access in northern climates.



They picked a location that had been damaged by a major flood in 2012, a choice that was supportive of efforts to rebuild after the event. The plot used to be home to a church but now is owned by the city of Duluth. The site is close to an acre and required a lot of work to prepare it for the greenhouse – including bringing in utilities and regrading it. It was also being used as overflow parking for the high school, so they had to figure out an alternative parking spot for the students. The entire lot will eventually be developed to also have raised beds, a pollinator garden, and an outdoor classroom. It is also located in close proximity to the Duluth community garden plots.

Management

The project was a partnership between CAD's Seeds of Success program, the city of Duluth, the Junior League of Duluth, and the Zeitgeist Center for Arts and Community. Seeds of Success is currently the primary operator of the greenhouse, with the other parties providing funding, site ownership, and educational support.

Another group that utilizes the CAD greenhouse are students from a transitional work class from the nearby school. They are on the autism spectrum and the class engages in projects that help develop practical skills throughout the community. They have come in to help put soil in the gutters and hang them. CAD expressed the need to find enough work for them to do, in order to maintain their visits to the CAD DWG.

Their general supply list for nearly everything that was ordered initially to start the CAD greenhouse included soil mix, equipment for harvesting, knives, brooms, hanging gutters, and the initial seeds, totaling a little less than \$3000. Additionally, they estimate 10 hours a week of work goes into operating and maintaining the space year-round.

Construction

Years of work went into the planning of the CAD greenhouse before ground was ever broken. Because those interviewed were not involved in that phase, they were unable to share much about the construction phase of this project. Architectural renderings from the start, as compared to the end of the project, look very different, so it can be assumed that changes were made throughout the construction process that dramatically altered the final greenhouse's size and its foundation's heat capacity.

Future considerations

Interviewees cautioned that the plot of land that gets chosen needs to be well thought out. Since their plot of land was owned by the city of Duluth, they had a lot of restrictions to comply with throughout the planning and construction process. They also had to work out a long-term maintenance agreement with the city.

One staff member met with the local small business development center to determine how much revenue they would get from the space every year. They calculated that the best-case scenario would be around \$7,000 annually. To date, they have not reached this level of production.



The south facing glazing and west facing door and window



The interior of the greenhouse with hanging gutters waiting to be installed

Photos provided by Community Action Duluth

Organic Consumers Association

Located in Finland, MN

Function

Organic Consumers Association (OCA) is a non-profit formed in Finland, Minnesota, in 1998 to pressure the federal government to keep strict organic standards. It now represents over 2 million online and traditional activists who also produce their own organic produce. OCA is using their DWG in Finland, in northern Minnesota's Arrowhead region, to grow greens that are sold at the Finland general store. More broadly, OCA views DWG's role as a technical solution that allows for local food systems to have fresh produce, even in the winter. Interviewees from OCA expressed reservations about the energy intensity involved in the construction and believe that we ultimately need to move towards seasonal eating.

The OCA DWG was built as part of a statewide initiative by RSDP that constructed five DWGs using the 2.0 design. This was the first of the greenhouses to be built in that project.

Management

The OCA DWG is run by the OCA farm manager. They expressed that it would be very difficult to have the greenhouse run by volunteers. As an example, they have faced issues with the upper windows not automatically opening and closing based on the temperature, forcing them to rely on manual adjustment every morning and night. If this is forgotten about, they risk losing the entire crop inside. They believe the best solution would be to have someone who is located in close proximity (in their case, living on-site) managing the DWG in conjunction with other chores like feeding chickens.

They are growing mustard, Chinese cabbage, Swiss chard, spinach, and some tropical plants like turmeric. They believe the best value per square foot is high-value crops like microgreens.

They host events like an open house in June. They also have classes through University of Minnesota Extension's Regional Sustainable Development Partnership. They reported that a lot of people come out to tour the greenhouse.

Construction

Drainage was really important to them when building the structure. The total cost for the structure was really high because the site that was chosen is very wet. They built the bottom of the insulated four-foot basement at the grade of the land then added fill around the basement foundation. This was the only way to keep the rock bed dry without the addition of a sump pump, which would have had a high electrical load over the long term. They viewed it as a high cost

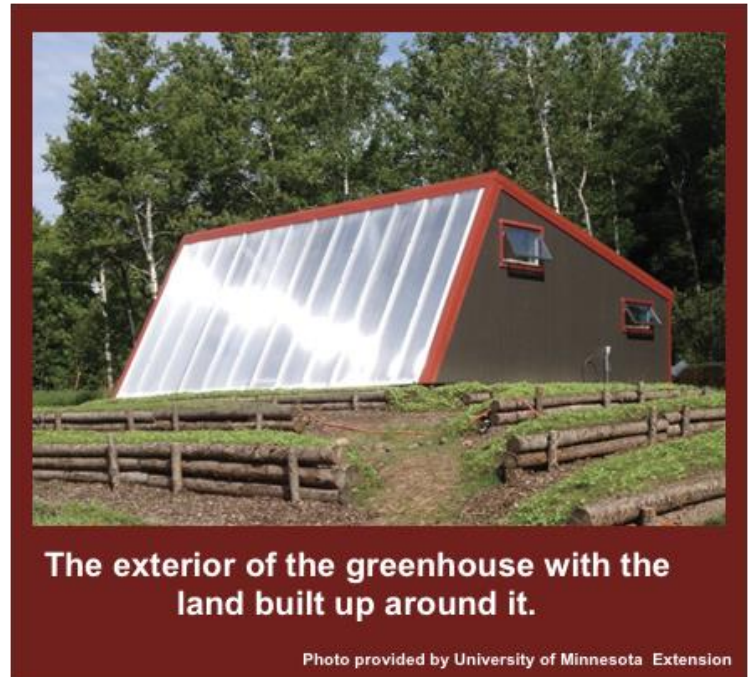
upfront but worth it since they are able to provide more food calories from a lower input of energy calories.

They paid a certified electrician because of the heat and moisture considerations. They also installed metal plumbing rather than plastic, which was called for in the initial design. Both were significant expenses.

Changes

If they were to rebuild their DWG, OCA would change the dimensions from 24 feet by 16 feet to be 20 feet by 16 feet, so the back wall would get sunlight during more weeks of the year.

The back part of the greenhouse is a large source of mold for them. In the three years they have used the greenhouse, they have had to repaint it twice with mold-free paint. This is caused by the warm, moist air from the greenhouse space getting sucked into the cold back room.



Future considerations

They are interested in the use of DWGs in addressing municipal waste through composting at institutional levels using soldier fly larva. They estimate it could reduce one third of the waste stream while building soil for agricultural purposes. Additionally, DWGs could be used for drying lumber.

They believe greenhouses are a wonderful resource for schools to help teach food literacy and that using them for education helps justify the cost. A DWG allows for a teaching space in the winter and the growing season matches the school year, unlike traditional farm-to-school programs.

They emphasized that non-profits should explore the economics around owning and managing a greenhouse. They need to consider the cost of labor, pests, and possible accidents, such as overwatering or windows getting left open, which would damage the crops. They also advise against flooding local markets with artificially low-priced produce if the greenhouse is paid for by grants.

Nemadji Research Corporation

Located in Bruno, MN

Function

Nemadji Research Corporation is a back-end data analytics vendor for hospitals. Their office is located in Bruno, Minnesota, in Pine County, in a converted former school building. On the south wall of the former gym, on the exterior brick wall, they built a 32-foot by 16-foot DWG. It was built in 2003 but was not utilized until 2015 because of a lack of funding to finish the interior electrical work and supplemental (backup) heat.

The main purpose of the greenhouse was as a beta test site to see if the greenhouse would hold heat and support an aquaponics system. While this does not align at all with Nemadji’s primary business, the employee who manages the greenhouse has experience in large-scale salmon hatcheries on the west coast. The aquaponic system inside the greenhouse supports 150 hybrid bluegills, which are characterized as hardy native fish. They can thrive in the water as cold as 40 degrees Fahrenheit in the winter and as warm as 90 degrees in the summer. This is compared to the more common fish for aquaponics, tilapia, which is a warm-water fish that would not be able to handle such cold temperatures in January and February. Nemadji would need to have the fish processed at a USDA-certified facility in order to sell them, but they are vital to the system by providing food for the plants in the greenhouse.

Management

The greenhouse is managed by a Nemadji employee who spends, on average, 30 minutes daily to maintain everything. Nemadji had an arrangement with Pine Habilitation and Supported Employment

(PHASE), a local non-profit that provides job services for adults diagnosed with developmental disabilities, traumatic brain injury, or severe and persistent mental illness. PHASE participants traveled the 20



South facing windows. The cloth is used to limit the solar gain for heat management during the summer.

Closed-loop aquaponics system

Tomatoes, peppers, and Swiss chard in the beds

Photo retrieved from Facebook

miles daily to work in the greenhouse, but it was not economically feasible for them to continue the partnership long-term given the small number of tasks that needed to be done.

The operating costs for the greenhouse are low, so much so that they barely notice it in their monthly electric bill. The only electrical equipment is three pumps on float switches and a timer that run for 15 minutes twice an hour. The monthly expenses are estimated to be about \$20 for electricity, \$15 for fish food, and half an hour of time a day to take care of everything.

The plants typically include peppers, tomatoes, lettuce, and kale. The greenhouse does have supplemental lighting that can be used if desired, but this year they are experimenting with not using it at all. This food, valued at approximately \$20 to \$30 a month, is donated to the daily salad bar and hot lunch offered through Catholic Charities for seniors in the community as well as Nemadji staff.

Schedule

cold-tolerant				heat-tolerant						cold-tolerant	
Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
lettuce				tomatoes						lettuce	
kale				peppers						kale	

Construction

When building their structure, they did not follow any blueprints. It was loosely based on a greenhouse in Wisconsin that was previously built with the assistance of Mr. Chris Reed. That greenhouse was built upon a heat sink consisting of 12 inches of sand and 12 inches of concrete. Regarding regulatory issues, the only requirement in Bruno was a building permit. They experienced some issues early on with mechanical components, but the facility has been running non-stop for about 4 years now.

Changes

One construction change they would make if they were to build it again would be to use double- or triple-walled polycarbonate for glazing. They currently have 16-foot panels of glass, which do not diffuse light as well and have a lower R-value (heat retention ability) compared to polycarbonate panels.

Future considerations

The team at Nemadji hopes to see the future as having a greenhouse on the side of every large building in all communities, helping with the ultimate goal of producing and consuming food locally.

Great Expectations School

Located in Grand Marais, MN

Function

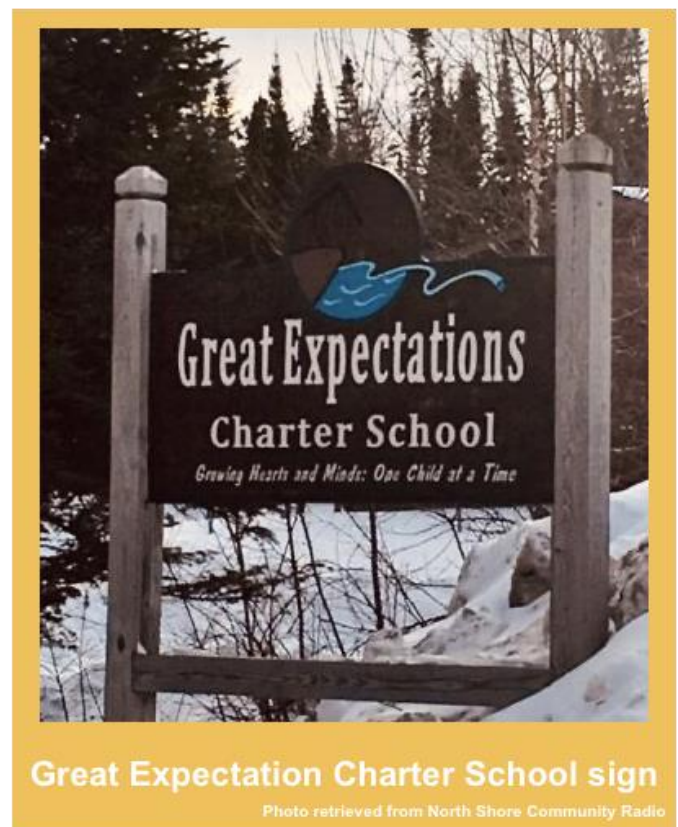
Great Expectations is a charter school located in Grand Marais, Minnesota, that serves 110 students. Their DWG is attached to the school, sharing the back wall with the school building. The purpose of the greenhouse was intended more for production than educational purposes. Last year they grew lettuce that was used in the school lunches. They started in February and food was grown through April. Between February and May the greenhouse becomes heavily used for growing garden plants for the school's annual fundraiser. They start from seed in individual classrooms under lights and, after first germinating, they are moved into the greenhouse.

The school staff have been using the space in less predictable ways that were not originally intended, such as for anatomical dissections, which produce too much smell to be done in the classrooms. This is specifically done in the winter since it is warm enough for students inside the greenhouse but not so warm that the smell becomes overwhelming. They also have a lot of shelving used for holding plants that is also sometimes used to hold student projects that have lots of glue or paint or need to dry or cure.

Management

The greenhouse project was handed off to the school after the funding was obtained. The school staff was in charge of managing the construction process. A collaboration between the YMCA, Cook County, University of Minnesota Extension and Community Education paid for a position for two years to get the greenhouse up and running. The employee met with the teachers and decided what to grow and put a program in place for future use.

The school originally did not have a teacher specifically tasked with managing the greenhouse. They recently decided to devote one staff member, who has previous production experience, to grow food for their lunch program in the greenhouse. This is because they see its main purpose as providing food.



Construction

The idea for the DWG emerged from hearing about Carol Ford and Chuck Waibel's greenhouse and their subsequent presentation in Grand Marais. Using a \$10,000 grant from the Northland Foundation and a crew made up entirely of volunteers, with two volunteer carpenters leading the construction efforts, the DWG was built at the school over one summer. They have an old design which is not as efficient and does not hold heat as well as the current models.

Changes

There are things they would do differently if they were to rebuild the greenhouse. Foremost, they have issues with it overheating in the summer. Originally, all of the greenhouse air vented to the outside, but with the expansion of the school building it became enclosed such that the venting goes into the school. In September and April/May, the excess heat is especially problematic. Having a way to vent into the school is great for part of the year but having an alternative to vent air away from the school would also be beneficial during warmer times of year.

Another thing to change would be to slope the roof a little more so that the snow will come off faster, since they have had issues with snow build-up that leaks into the greenhouse. In addition, they would rather have the top covered and insulated, and not allow the sun through at the top. During the winter the low sun comes through the glass, but when it gets higher, the greenhouse gets too hot.

The following are needed to retrofit their structure to make it comparable to current designs:

1. They would need to add a concrete cap on the foundation to better hold heat.
2. The removal of the fan that pushes air down into the rocks, which they now know does not work very well. It would be better to have a fan below to push air through the tubes into the gravel.
3. They would need more ventilation if they wanted to use the greenhouse during shoulder seasons or summer because it gets too hot inside during September and April/May to be used. They accidentally remedied this by adding a hole in one side that they have not fixed yet, but this is obviously not a permanent solution.

Future considerations

The manager encourages anyone building a DWG at a school, even if they have a clear idea of how they want to use the greenhouse now, to spend time during the planning and building process to explore ways they can design the space to be more flexible, allowing it to be used either for teaching or for other functions during the off-season.

Lac qui Parle Valley High School

Located in Madison, MN

Function

The Youth Eco Solutions (YES!) team of students are the main users of the DWG located at Lac qui Parle Valley (LqPV) High School. They previously had an indoor production area that grew plants using grow lights and were inspired by the passive-solar greenhouses in Montevideo and Milan. The group and advisor applied for a farm-to-table grant for schools from the Statewide Health Improvement Program (SHIP) and a youth gardening grant. The school district financed the rest, originally believing it would be around \$12,000 total. The final total ended up more than \$30,000.

The produce went to the school lunch program for the first few years. After the salad bar line was removed, the products began being sold as a CSA. They decided on a CSA so that they would be able to move towards self-sufficiency to buy their seeds and soil mixture (as described in *The Northlands Winter Greenhouse Manual*). When they have had large groups of students, they have been able to sell four shares with recipients receiving a box of greens every week for 12 or 16 weeks. They believe if they continue down this route, they will be able to pay off the greenhouse. This year they are selling the produce to the staff at the school.

Management

The YES! advisor is a teacher who manages the club as an extracurricular activity. They manage the students' schedules to ensure the greenhouse is maintained and the plants are being properly cared for. The students go in the LqPV greenhouse during open class periods in their school schedules. The students are also responsible for watering over weekends and breaks.

They sign up online and the advisor sends out reminders. The school is located a significant distance from some students' homes, possibly up to a 30-minute drive.

They grow using Johnny's seeds. They grow different leafy greens like mustard greens and pea sprouts. It is estimated that they grow a few hundred pounds per year, similar to New London-



The process of constructing the foundation



The interior of the greenhouse with hanging gutters and raised planting beds

Photos provided by Lac Qui Parle HS staff

Spicer (NLS) production capacity that is described in the next case study. When the produce went to the salad bar for the students, they did taste-testing with the students for them to try the different greens they were producing, and they found it to be very successful.

Construction

They based the LqPV DWG design off of Carol Ford and Chuck Waibel's and sought their assistance throughout the process. They started in the fall of 2011 with the foundation, doing free-form insulated walls and poured cement that was filled with rock and drain tile tubing. After the foundation was done, construction halted. The following spring was very wet and rainy, which pushed construction back until the fall. They hosted community volunteers on particular Saturdays, and also connected with "Betty the Blue Bus," a traveling volunteer couple who spent a few weeks managing the construction. This was key because having students work on the construction was very difficult, with turnover every 49 minutes (the length of class periods). They finished in November and started planting the week before Christmas break.

Having students build the structure created issues. They do not have an airtight structure, so a lot of heat escapes. On the other hand, they do not have any moisture or mold problems that they have heard others experience.

Even with all of the free labor, it still cost about \$30,000 just for the materials and more for the electrical work. This went well over the original estimate. When they reached \$20,000, it was already half-built, and so they just continued with the project. The produce that was donated to the school lunch program was deducted from the amount of money the YES! group owes the school district.

Changes

When considering things that could be changed with the LqPV greenhouse, a few things were mentioned. The greenhouse is large enough to fit 30 to 40 kids, but that size also makes it difficult to heat. They would have liked to use a geothermal system, similar to the one used by NLS to bring up 50-degree ground air into the greenhouse, rather than the electric heat they currently have. They also would have used treated wood or cedar on the support beams behind the polycarbonate sheeting.

Future considerations

They have talked about working with a local grocery store to sell produce there, but this has not been pursued yet. They have also been approached by a local flower shop to possibly partner in growing container plants that would be ready to sell on Mother's Day.

New London-Spicer High School

Located in New London, MN

Function

The Youth Eco Solutions (YES!) student group members are the primary users of the DWG at New London-Spicer High School from October to March. They raise a cool-season crop or leafy green varieties. Then in March, the FFA chapter uses the greenhouse to raise vegetable seedlings and annual flowers to sell at a plant sale that opens Mother’s Day weekend. The money raised goes to the FFA chapter.



Management

The greenhouse is volunteer-run with multiple student groups using it in various capacities throughout the year. Typically, the YES! group and advisor take care of most of the lettuce until March. The lettuce they harvest is served to students in the cafeteria.

The FFA chapter then works in the DWG. They order plugs and seeds of vegetables and flowers. This is the switch to warm-season crops. They have a huge plant sale which typically opens Mother’s Day weekend, and they sell plants for two or three weeks. Last year they sold out in a week and a half. Last year they did all types of vegetables and annual flowers. The money goes to the FFA chapter.



A plant science and a landscaping class in the spring take care of the flowers and vegetables. A local parent volunteers their time to water on the weekend. Ultimately the upkeep responsibility is on a teacher in the agriculture department. During school breaks, the teacher and volunteer parent are responsible for watering.

Schedule

YES! Group					FFA Chapter		
Oct	Nov	Dec	Jan	Feb	March	April	May
mixed lettuce					vegetables		
					annuals		

Funding

They received grants from a variety of organizations, including Clean Energy Resource Teams (CERTs) and the Minnesota Association of Agricultural Educators. They received several local grants as well. They used Carl Perkins money, which is a federal grant available to vocationally-certified schools to purchase equipment.

Construction

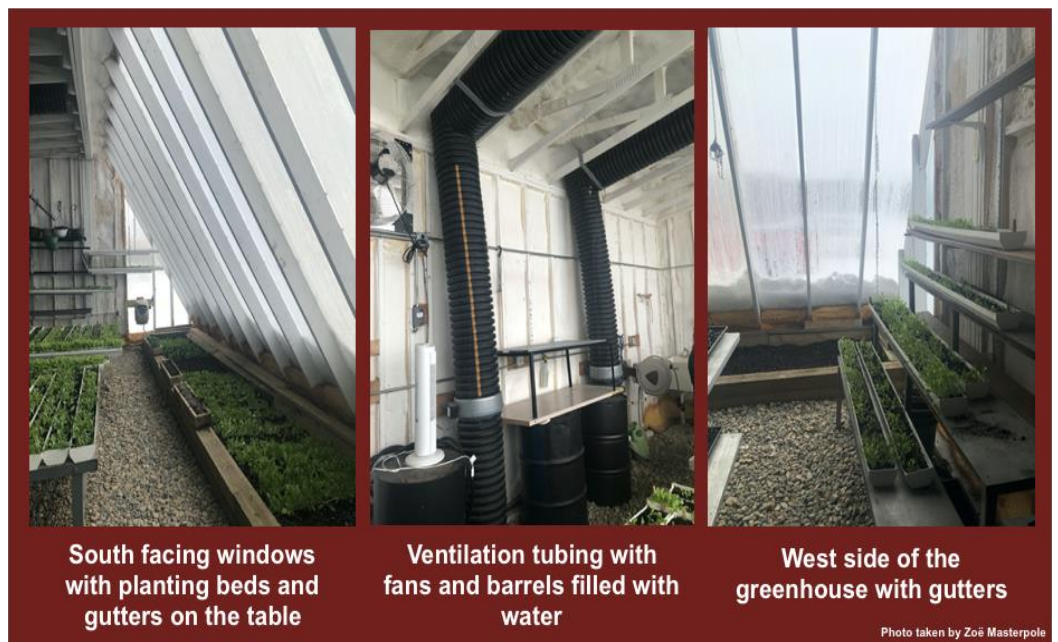
Their growing area is 30 feet by 20 feet, and the cold storage space behind the growing area is 30 feet by 10 feet. They based the design off pictures from Carol Ford and Chuck Waibel’s DWG in Milan, Minnesota. They decided to use a larger pipe than in other designs (as seen in the middle photo below), rather than the smaller, closer-together ones for the foundation. They also buried 8-inch well pipes around the perimeter of the building, so they are using geothermal heat as well, capturing 50-degree underground air and blowing that into the greenhouse. This helps lower the temperature when it is too warm inside and helps raise the temperature during the winter months.

During construction, excavation was one of the biggest costs because they dug a huge hole and had to purchase 3000 cubic feet of rock for the entire space, which was more expensive than they expected. But there were areas that cost less than anticipated. For example, a former student who has a construction company ran the waterline and did not charge them anything.

Changes

If they were to do it again, they would put poly sheeting on one more wall instead of maximizing insulation, since they have never had issues with lower temperatures inside. When they are growing lettuce, light does not matter as much, but with things like

tomatoes, they need lots of sunlight and they do not use any supplemental lighting.



Wadena-Deer Creek Senior High

Located in Wadena, MN

Function

The main purpose of the Wadena-Deer Creek (WDC) DWG, in conjunction with the high tunnel they manage, is to provide fresh produce for the school lunch program. Additionally, students work in the greenhouse as part of their plant science curriculum and career development. They are working on ways to get more classes involved in the greenhouses.

Management

The greenhouse is managed by a paid employee who spends 20 to 25 hours a week, year-round, working in the DWG and the high tunnel. They emphasized the need for a paid, dedicated staff member. When the DWG was first being planned, the FFA advisor/shop teacher was expected to take on the additional responsibility. Using other greenhouses in the area as examples, they pled their case to have a dedicated staff member, either a second ag teacher or a greenhouse manager, rather than putting that work onto a teacher without lowering their course load. The school district ended up going with a greenhouse manager. They have had three different people in that role since 2013.



The greenhouse manager with the produce stand. Produce from the greenhouses are sold during the summer months to raise money for inputs like seeds.

Photo retrieved from Superstation K106

The manager works with all of the teachers if they need something involving the greenhouse. The greenhouse manager has brought microgreens into the 6th-grade classroom. They help the home economics teacher when they are doing the international cooking class to grow some of the spices and microgreens for sandwiches. The kindergarteners come out and pull carrots. In the spring, the elementary kids all come out and plant a flower for their mom for Mother's Day. It is not formal teaching, since the manager is not a teacher. This year they grew pumpkins and brought them into the special education class so the students could see what was inside. In the summertime, they have a summer recreation class, one with kindergarteners to 3rd graders and another with 4th to 6th graders doing activities. The students plant a garden and then weed and water it all summer.

Schedule

High Tunnel



Deep Winter



Construction

This project was a cooperative effort between local, county, and statewide organizations. The University of Minnesota Central Region Sustainable Development Partnership (CRSDP), Stimulating Economic Progress (STEP), Wadena Elks Lodge, Sustainable Farming Association of Minnesota, and Health4Life were all involved in the funding and/or building process. They purchased their greenhouse from Polytex, a Minnesota company.

The WDC DWG is unique in its use of retractable plastic curtains to control heat. There are air tubes and fans that pump air into the tubes, based on the temperature. The air acts as insulation in the wintertime. During the summer, when they are not needed, they deflate, and the air is sucked out. They are on both sides, and right at the peak there is another set of curtains.

They view the heat sink as supplemental to the propane, rather than the other way around. Sunlight, specifically the quality, is a big issue for them in the winter months. They specified that getting enough, and the right type of light, is an issue in late December into January.



Future considerations

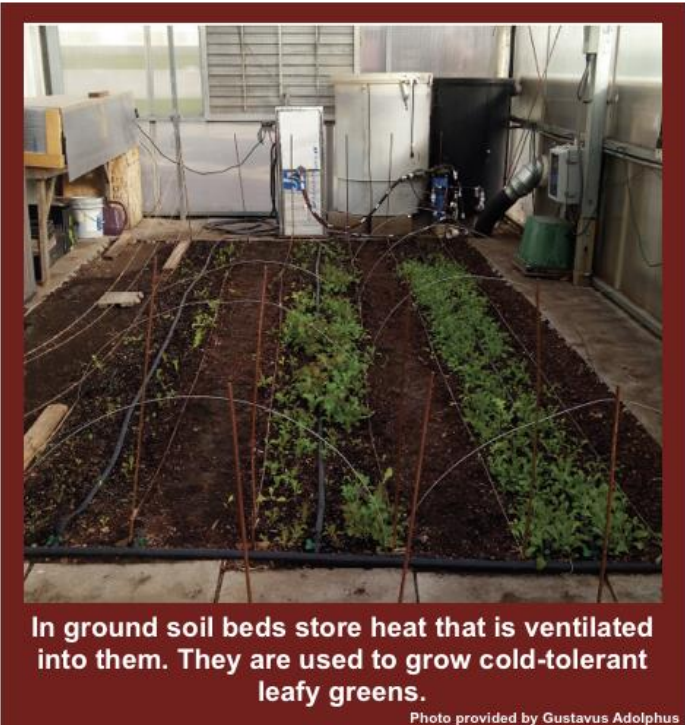
They are working towards incorporating more and more students into the greenhouse. They acknowledge that putting the burden on teachers to plan activities that involve the greenhouse is strenuous on top of their current workload, so the greenhouse staff is leading activities.

Gustavus Adolphus

Located in St. Peter, MN

Function

The DWG at Gustavus Adolphus is part of a larger complex that contains an industrial food composting facility used by the school. The DWG is used to produce leafy greens that the school buys and incorporates into its dining services. They chose the DWG model because its growing season matches well with their school year. But that is not its only purpose; it is also used for co-curricular education, access to fresh and local food, a demonstration for a circular economy with recycling food waste, and a good learning space for the students to learn management and organizational skills. In addition to producing vegetables, the building is home to an aquaponics system that grows tilapia.



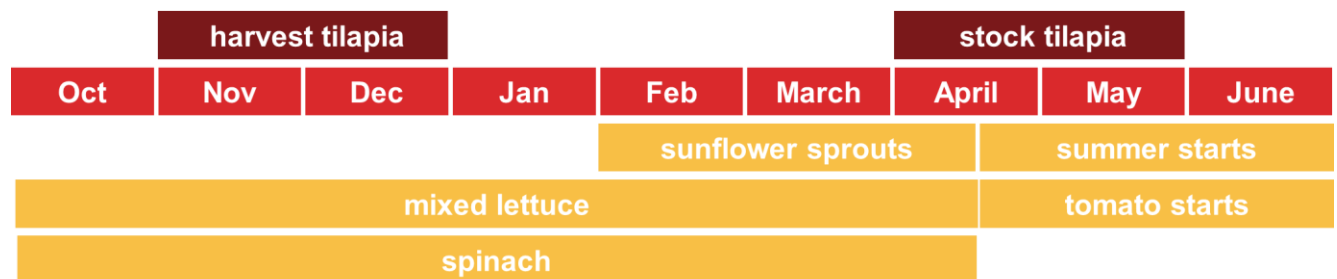
In ground soil beds store heat that is ventilated into them. They are used to grow cold-tolerant leafy greens.

Photo provided by Gustavus Adolphus

Management

The DWG is managed by a combination of student organizations and student employment. The students work as interns over the summer and the organizations recruit volunteers and plan learning activities involving the DWG. These students are overseen by a professor who also utilizes the DWG in their courses.

Schedule



Construction

They picked a location that was not near other buildings so the odor from the composter would be less of an issue. They used modular construction of all the components involved in the composting and greenhouse system. They adapted a greenhouse kit from Rimol Greenhouses to become a lean-to and added it to the side of the building holding the composting machine. The Rimol Greenhouse company was able to provide engineering documents that satisfied building inspection requirements. Their composting facility fell under the backyard composting provisions in city code. Additionally, Gustavus Adolphus College planning staff handled the building and electrical inspections.

Changes

They do not have insulation (as can be seen in the photo on the right), so their greenhouse does experience freezing temperatures inside during the winter. They would have liked to use more of solar principles and made it more of a weather-tight structure. They currently have a transparent roof, but they said they do not need it.

They also said they wished they would have purchased a device that captures the heat from the composter and transfers it into fluid, allowing for the separation of the greenhouse and the building housing the composter.



Future considerations

For those looking to replicate the model of having student groups run the greenhouse, there is a learning curve that Gustavus has experienced. Students who have never worked in a greenhouse before have had to adjust to the lower level of watering needed, which has slowed production. They have struggled to start enough plants in the fall to continue production throughout the fall semester. They are also at the mercy of student interest and availability. This means that they have a tough time growing in December when light is scarce, and students are gone for the holiday break. This continues into January with a reduced student population during the January-term.

In the future, Gustavus researchers want to find ways to adapt pre-built garden sheds to be used for people in their backyards with minimal budgets. They are currently looking into funding for research on the topic.

Cited Resources

Background

University of Minnesota Extension

<https://extension.umn.edu/rsdp-happenings/deep-winter-greenhouses-hold-exciting-possibilities>

The Northland Winter Greenhouse Manual by Carol Ford and Chuck Waibel

<https://www.farrms.org/product-page/the-northland-winter-greenhouse-manual>

Cold Climate Greenhouse Resource Publication

<http://www.cura.umn.edu/publications/catalog/cap-186>

Bemidji Community Food Shelf

Bemidji Food Shelf Website

https://bcfsmn.org/urbanfarm_bcfs/deep-winter-greenhouse/

News Release

https://drive.google.com/file/d/1zv8CfSrbRpyMWQkGg0iKWxH-ERad_c5B/view

Community Action Duluth

Minnesota State Senate Report

<https://www.senate.mn/committees/2015->

[2016/3083_Natural_Resources_Economic_Development_and_Agriculture_Budget_Division/Deep%20Winter%20Greenhouse%20Project%20Overview.pdf](https://www.senate.mn/committees/2015-2016/3083_Natural_Resources_Economic_Development_and_Agriculture_Budget_Division/Deep%20Winter%20Greenhouse%20Project%20Overview.pdf)

City of Duluth Press Release

<https://duluthmn.gov/media/WebSubscriptions/31/20170906-31-4751.pdf>

Organic Consumers Association

Lake County News Chronicle

<https://www.lcnewschronicle.com/news/4223700-new-greenhouse-unveiled-finland>

Midwest Organic & Sustainable Education Service

<https://mosesorganic.org/broadcaster-dwg/>

Nemadji Research Corporation

Nemadji Research Corporation Website

<https://nemadji.org/>

Nemadji Research Corporation Facebook

<https://www.facebook.com/nemadjimn/>

Great Expectations School

Great Expectations School Website

<https://www.greatexpectationsschool.com/>

North Shore Community Radio

<https://www.wtip.org/great-expectations-school-news-march-15-2019>

Lac qui Parle Valley HS

West Central Tribune

<https://www.wctrib.com/news/1893405-lqp-valley-greenhouse-going-help-near-far-video>

New London-Spicer HS

West Central Tribune

<https://www.wctrib.com/news/2354000-nls-passive-solar-greenhouse-could-have-impact-entire-county>

Wadena-Deer Creek HS

Wadena-Deer Creek High School Website

<http://www.wdc2155.k12.mn.us/>

Wadena Pioneer Journal

<https://www.wadenapj.com/lifestyle/4625157-ready-veggies-wdc-produce-stand-open-business>

MPR News

<https://www.mprnews.org/story/2018/11/13/school-grown-produce-teaches-students-to-eat-their-vegetables>

Wadena -Deer Creek Public Schools Website

<http://www.wdc2155.k12.mn.us/wolverine-news/2013/7/1/wdc-breaks-ground-on-greenhouse>

Gustavus Adolphus

Informational Poster

<https://sites.google.com/gustavus.edu/gac-composter-and-greenhouse/>

Mankato Times

<http://mankatotimes.com/2016/03/06/local-high-school-students-participate-in-winter-workshop-at-gustavus/>

Funding and Resource List

The following are sources of funding that are cited throughout the case studies. This list is meant to act as a starting point for anyone looking into funding a non-profit DWG. The availability and requirements for funding differs by source.

Source	More Information
Carl Perkins Grants	https://cte.ed.gov/grants/funding-opportunities
Clean Energy Resource Teams (CERTs)	https://www.cleanenergyresourceteams.org/tools-guides
Coke Partnerships	https://www.coca-colacompany.com/shared-future/communities/the-coca-cola-foundation
U.S Economic Development Administration (EDA)	https://www.eda.gov/funding-opportunities/
Grow Rural Education - Bayer Fund	https://www.americasfarmers.com/grow-rural-education/
Minnesota Association of Agricultural Educators	https://www.mnaged.org/index.php
Northland Foundation	https://northlandfdn.org/grants/
Statewide Health Improvement Partnership - Minnesota	https://www.health.state.mn.us/communities/ship/index.html
Sustainable Farming Association of Minnesota	https://www.sfa-mn.org/
Youth Eco Solutions (YES!)	https://yesmn.org/
Youth Garden Grant	https://kidsgardening.org/2019-youth-garden-grant/