BIOMASS-HEATED GREENHOUSES

A HANDBOOK FOR ALASKAN SCHOOLS AND COMMUNITY ORGANIZATIONS

Sponsors

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The Alaska Energy Authority (AEA) is an independent corporation of the State of Alaska. As the state's energy office, they implement innovative programs to address the high energy costs in Alaska.

The USDA Forest Service and AEA hope this handbook will serve as a guiding document to help cultivate sustainable, self-sufficient, and resilient communities throughout Alaska.

Project team

This handbook was authored by a collaborative team led by the Cold Climate Housing Research Center (CCHRC), with guidance from a steering committee formed by the sponsoring agencies.

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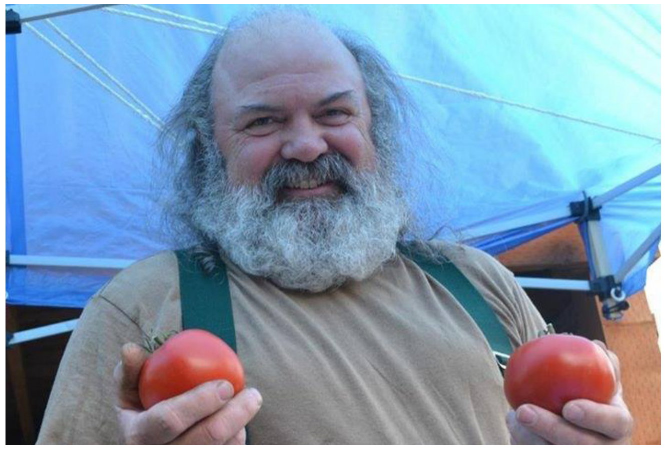

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Motivation

The goal of this handbook is to provide a guiding document for schools and community organizations wishing to implement a biomass-heated greenhouse. However, the overall philosophy behind this project is to help cultivate sustainable, self-sufficient, and resilient communities in Alaska. In that light, we have included projects that feature biomass heating, or greenhouses, even if they are not combined.

With these goals in mind, this handbook was built around three core principles:

Alaskan heat

Locally sourced biomass fuels provide a renewable, reliable energy source. Biomass-heating systems also provide local jobs, keeping energy dollars inside a community. Finally, local heat sources promote the energy independence and self-sufficiency of Alaska communities.

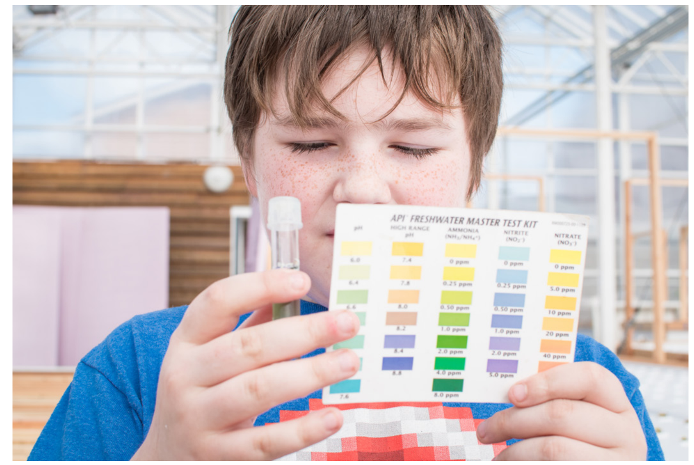
Alaskan produce

Feeding ourselves, our children, students, and communities nutritious, locally grown food has many benefits: healthier bodies; tangible connections between growers, preparers, and consumers; an innate understanding of where our food comes from; improved quality of life; and lower health care costs. Growing our own food fosters a connection between people and place and empowers individuals to take charge of their own healthy eating.

Alaskan knowledge

This handbook shares the hard-earned knowledge of Alaskans who already have or are in the process of implementing separate or combined biomass and greenhouse projects. This collective source of knowledge will support future generations in advancing projects that improve our communities and our state.

Inspiration for this handbook comes from Alaskan schools already using biomass-heated greenhouses, such as the three below:



The Southeast Island School District operates 4 biomass-heated greenhouses in Thorne Bay, Kasaan, Naukati Bay, and Coffman Cove. Each biomass-heated greenhouse provides fresh produce to the school cafeteria and surrounding communities, jobs for district students, and an opportunity for teachers to bring textbooks to life.

The Tanana City School District is implementing a biomass-heated greenhouse project, with students documenting construction of the greenhouse frame and studying options for planting systems during classes. In fall 2016, the community put up the frame and glazing of the greenhouse.

The Alaska Gateway School District has a biomass -heated greenhouse at the Tok School. Produce such at tomatoes, lettuce, and cucumbers that are grown in the greenhouse are consumed within all seven school cafeterias in the district.

To the reader

This handbook covers basic information on planning, building, heating, and managing a biomass-heated greenhouse. It is meant to be comprehensive, but must be tailored to the geography, goals, and resources of individual communities.

Why biomass-heated greenhouses?

Woody biomass refers to any fuel that is derived from plant materials, including everything from cordwood logs to sawdust leftover from timber mills. Alaska has a wealth of biomass resources and a long heating season, but biomass heat does not make sense everywhere. However, with over 500 schools in the state and fewer than 10 currently heated with biomass, using a local biomass fuel source has a lot of potential.

A biomass-heated greenhouse provides a warm, green respite during cold winters. It also provides fresh, local produce in a state where a large portion of food is imported. Greenhouses and biomass-heating systems also provide an opportunity for hands-on education in traditional subjects and electives.

Who should use this handbook

The main audience is Alaska schools and community organizations in Alaska. While we hope this handbook is useful to other groups, please keep in mind that some references and suggestions may need to be modified to fit a specific project.

This handbook is written for organizations that want to implement a biomass-heated greenhouse. However, we have also included examples of both greenhouse and biomass projects that are not combined to illustrate certain features or considerations. Readers with the interest and/or resources to implement only a greenhouse or only a biomass heating system may still benefit from chapters herein.

How to use this handbook

This handbook has eight chapters presented in chronological order, beginning with the decision to install a biomass-fueled greenhouse. There isn't enough room to provide details on each specific subject, however, there should be sufficient information to give a sense of the required involvement, starting points, and resources to learn more. We do not expect readers to be experts after finishing this handbook, but hope to instill enough confidence to get the planning process started.

Bell peppers grow in a high-wire vertical hydroponics set-up located in one of the research greenhouses at the University of Alaska Fairbanks (heat provided via a district loop of recovered heat from the university's power plant). Greenhouses extend the growing season in northern latitudes, especially in locations that experience only a few months without snow cover on the ground.

1

DECIDING

IS A BIOMASS-HEATED GREENHOUSE RIGHT FOR MY ORGANIZATION?

PRECEDING PAGE: The hydroponics system in a biomass-heated greenhouse in the Southeast Island School District.

What is possible?

Dream big! It may take years to reach your final goal, but don't let that limit your initial vision. Biomass-heated greenhouse projects large and small can provide numerous benefits to communities. As each benefit builds on the others, the resiliency of the entire community increases.

Healthy people: Locally grown produce is fresher than vegetables that have traveled thousands of miles, as is often the case when food is shipped to rural Alaska. Additionally, knowledge that it is locally grown can inspire people to eat more vegetables or try something new. In the winter, a biomass-heated greenhouse has bright green plants, an abundance of oxygen and humidity, and the opportunity to work with a team planting, weeding, and harvesting.

Sustainable local economy: Heating with local biomass and growing food locally creates an opportunity for local labor as well. This is a great benefit in areas with high unemployment rates, as many communities in rural Alaska have. Using local biomass and consuming local food also allows us to displace imported heating fuel and food, keeping more dollars in a community.

Low environmental impact: Eating local food reduces greenhouse gas emissions caused by shipping food long distances and by large-scale farming operations. Biomass heating, especially when waste wood is used as fuel, is renewable. Biomass heating also can be incorporated into a community's forest management plan.

Affordable, stable heating costs: Alaska's many biomass resources include cordwood, driftwood, chips, and pellets manufactured with biomass waste products. With proper management, biomass is not subject to the same price fluctuations as fossil fuels and biomass harvesting can provide local jobs.

Forest health: Alaska contains millions of acres of forest, including the Tongass and Chugach National Forests. A properly managed forest reduces the chance of forest fire and maximizes community benefits such as recreation, economy, and subsistence. A harvest plan will establish harvesting guidelines that balance the demand for biomass fuel with soil health, water quality, and wildlife habitat.

Educating the next generation: Biomass-heated greenhouses provide an opportunity to relate the lessons in textbooks to the real world. Not only do they act as a living laboratory for science classes and an inspiration for the arts, they give students the opportunity to develop skills in fields such as science, agriculture, business, and forestry.

What are your goals?

The first phase of a project idea is to identify locally available resources, solicit input from stakeholders to develop a vision, and build a step-by-step project plan.

Vision: Meet with stakeholders and invite everyone to dream about the possibilities of a biomass-heated greenhouse project. Goals should be big and unlimited at this stage. As the community comes together to build a long-term vision, it needs to be recorded to provide the guidance and direction for the next steps of the project.

Priorities: A short list of priorities helps the project team decide on specific objectives. Examples of priorities for a biomass-heated greenhouse could be educational activities, production of fresh vegetables, maximizing yields, providing local jobs, or making a profit. It may not be possible initially or even over time to attain all of these priorities. For instance, if the greenhouse has dedicated space for students to do art, there may not be enough space for a large quantity of vegetables. Perhaps funding is an initial issue with requirements for a short building payback, leaving other goals at a disadvantage. Priorities are therefore re-evaluated as the project develops and may evolve along with changes in local needs, resources, priorities, and community concerns.

SMART objectives: The objectives should be SMART – specific, measurable, assignable, realistic and time-bound. To determine the objectives, consider the long-term vision and then establish priorities and realistic milestones. Expect bumps and setbacks along the way. Learning from what works and what doesn't is part of developing a successful project.

> "[Students] will have the skills they need to eat better, grow their own food, start a business, and be able to stick around on the island if that's what they want to do."
>
> - Colter Barnes, Principal, Southeast Islands School District

The community of Tanana is in the process of setting up a greenhouse at Maudrey J. Sommer School. Students wrote the following statements during project planning.
Mission: We will grow fresh, healthy food utilizing teamwork with the school and community. We aim to create a movement to educate students about subsistence gardening. Our greenhouse will be a laboratory for developing food security and sustainability.
Vision: Fresh food, teamwork, community involvement, healthy
Priorities: Feed staff and students, get out of the classroom, teamwork, start a movement, fresh food, taste good
First objective: Construction of the greenhouse building envelope from a kit in Fall 2016. Begin education through student documentation of the construction with the eventual goal of creating a greenhouse manual and documentary film.

Do you have a project champion?

A biomass-heated greenhouse is an involved, long-term project that requires project champions to be identified up front. These are the people who will keep momentum strong. The project champion may be identified and acknowledged through a memo or job description, or the position may take shape naturally during early project meetings. Either way, the project champion will be instrumental and highly involved in keeping the project moving toward the final vision.

Sample tasks for a project champion during project planning:
Point of contact: One individual should serve as the point of contact for the project.
Documentation: Project goals should be documented and available to team members and the community. Where will the long-term project vision and short-term milestones be written down?
Keeping the plan realistic: Goals and tasks should match project team and community capacity.
Delegating: While the project champion will complete some tasks, many will need to be assigned to others in order to reach short-term milestones on the desired timeline.
Scheduling team meetings: Regular team meetings allow project participants to share progress, troubleshoot, and plan next steps.
Community engagement: Meeting with community members and stakeholders provides a path for comments and concerns. Groups to engage may include tribal and city councils, planning commission, and school boards.
Developing community capacity: Projects may require capacity that does not exist in a community, and here a project champion can work to arrange for training or new hires that help build capacity for future project phases.
Planning for succession: Preparation for succession is important in the event a project champion may need to leave the project for a variety of reasons. Recruiting new team members, training and division of tasks among project participants, and maintaining good documentation of current and past tasks can ease a transition of project champion roles should the current champion need to leave.
Staying enthusiastic: This includes helping the team to do the same.

A project champion does not have to be one individual or even one organization. Seeking partnerships is often advisable as work for a single or group of tasks can be shared. For instance, a greenhouse might partner with a restaurant, where the restaurant owner provides initial funding and a market and the greenhouse manager figures out how to heat, build, and manage the greenhouse. The partnership just needs to make sense for your goals and community.

One final note on project champions–cultivate diversity in your team. An arrangement with a single person doing most or everything is unsustainable for most projects. Working with team members allows for a division of tasks, more input, and heads for planning.

Southeast Island School District Project Champions

These individuals have led the implementation of four biomass-heated greenhouses at schools on Prince of Wales Island.

Colter Barnes, principal at the school in Coffman Cove, is also the greenhouse manager for the district. He helps develop lessons, curriculum, and resources for teachers to incorporate the greenhouse into their classes.

Superintendent Lauren Burch spearheads the biomass boiler and greenhouse projects. His motivations include improving school lunches, bolstering the local economy, and fostering student job skills.

Priscilla Goulding, federal programs and grants manager, works to procure funding for greenhouses. Her main focus is a plan for financial sustainability for each greenhouse.

Jonathan Fitzpatrick, maintenance supervisor and biomass boiler project manager, is managing the biomass boilers and overseeing their maintenance and operation.

Community support and communication is important. For instance, when planning the greenhouse at Tok School, Assistant Superintendent Scott MacManus met with local farmers to ensure that the greenhouse would not compete with other local farms.

Do you have community support?

Just as important as designating a project champion is the need for community support. Community investment in the project is an important part of project planning. This is especially true in Alaska, where the small populations in many communities make the need to work together a priority. To begin, it is helpful to assess your community and identify stakeholders:

What are local attitudes toward biomass? Toward greenhouses? Are there existing biomass heating or greenhouse projects in the area? What do people like about them? What do they dislike? What roadblocks exist?

How do your neighbors feel about having a biomass-heated greenhouse nearby? Do the local government and tribal council support the project? Does the local planning commission have any input on the project plan?

What changes might your project bring to the area? Will the biomass component involve harvesting local trees? Increased traffic along certain routes caused by biomass processing? Where will the greenhouse be built? Will the lights affect other buildings? Where will plant waste go?

Can members of the community fill any resulting jobs? Is training available for the type of skills needed?

Who will pay for the project? How will local organizations contribute? Will the school district or local government pay for some of the cost up front? Will community members volunteer time or donate items? Where will the produce be sold?

The next step is to address community support directly in your project plan:

1. Write a draft project plan for residents to read and evaluate. It should give an overview of the project, including information about goals, timelines, and resources.
2. Meet with key stakeholders in the community–everyone from neighbors, local government officials, planning commissions, fellow farmers or greenhouse managers, and people operating biomass heating systems. Be sure to talk to both members of the community who are enthusiastic about the project and to those who might have concerns. Seek out comments, criticism, and encouragement.
3. Use this feedback to revise your project plan. Fitting it to the community will bring added support and sustainability.
4. Plan regular methods for community involvement and feedback. This could include formal meetings with stakeholder groups, public forums, an annual open house or harvest party, a flier, or a mailer. Be open to make adjustments as the project plan is tailored to the community.
5. Share your successes! Let community members, local government officials, tribal council members, and neighbors know about the benefits of the project. Are students eating fresh produce from the greenhouse in the school cafeteria or gaining job skills? Was biomass purchased locally to use to heat the greenhouse? Publish a newsletter, give a presentation, or send a team member to do a local radio interview to share new accomplishments.

Is a biomass-heated greenhouse a good fit for my organization?

A project champion and community support will put you on the path to success. But the third leg of the triangle is locating resources. Biomass-heated greenhouses require a number of inputs; fortunately, for many Alaska communities, resources and capacity are locally available.

One step during initial planning is to evaluate local resource availability. Lacking a necessary resource may not doom your project, but know that your project team must be creative. You will have to decide whether or not the community can build up the needed capacity, whether a resource can be delivered and, in either case, whether or not it is worth the time and effort. The questions that follow are meant to guide your discussion.

> "What we are realizing now is that all energy is local, like all food is local. One of the things we have to look at when we are trying to get off of fossil fuel dependency is what resources we have locally."
> - Karen Petersen
> University of Alaska Fairbanks
> Cooperative Extension Service

Biomass: Not only do biomass heating projects require a steady supply of fuel in the form of cordwood, wood chips, or pellets, they will need a method to transport, store, and process that fuel. For instance, will local roads support trucks of cordwood being delivered to your site? Do you have a proper dry storage area for your fuel–a hopper for pellets or a shed for cordwood? Does local zoning permit a biomass appliance?

Human capacity: Can local builders complete greenhouse construction? Who will get a growing system operational? Will someone be able to troubleshoot issues with the biomass heating system? What about business management skills? Who can do daily operational tasks such as chopping wood and watering plants? Is anyone qualified to teach an agriculture class? Make a list of necessary skills and think about who could provide them in a formal or volunteer capacity. If not, research training possibilities and find people interested in learning the needed skills.

Greenhouse: To begin, do you have the space to build the greenhouse? Does it have natural light, room for a building with growing and storage space, and access to water and electricity? Who can install control systems for temperature, humidity, and light? Where will plant waste go? If you are planning to produce vegetables for sale, can trucks access the space to pick up produce?

Market: Are you planning to sell the vegetables you produce? If so, have you identified potential buyers, such as the local school, restaurants, or community members? What will the process look like from harvest to final sale–do you need a washing station, storage space, transportation, or a market stand? Talk to potential consumers; is there demand for what you plan to grow? Are they willing to experiment along with you?

Next steps

Now it's time to move past the idea phase and write a formal project plan. This plan will be an official project document and will help you inform stakeholders, search for funding, and ultimately break ground on your project.

Draft a project plan. See [Chapter 2: Planning] for information on how to draft your vision, priorities, and objectives as well as how to address participation, insurance, safety, and management.

Seek input on the project plan from team members, potential staff or volunteers, stakeholders, the local government and tribal council, the local planning commission, and community members. Ask for comments, hold meetings to discuss the plan, and solicit feedback from other regional project leaders who may be able to share advice and lessons learned. Use this input to revise your plan so it provides a clear path forward for your project.

You may find that a wise next step is to perform a feasibility study–a small report that looks at local capacity, assesses the practicality of the project, and compares advantages and disadvantages to alternative options. Feasibility studies can be especially helpful in evaluating a potential biomass heating system in your region by comparing it to other local heating options. These studies might be done formally via a third-party organization, or could possibly be done as a class project with students looking at local resources and costs or conducting a market study. Results from a feasibility study will make your project plan stronger by identifying gaps and finding alternatives.

Part of your project plan will address financial management and stability, but now is the time to search for capital funding and think about supplementary funding for operations. Having a plan in hand will show funders you have put serious thought into the project, addressed community concerns, and come up with a realistic timeline. In short, it shows funders the project is sustainable.

Repeat, repeat, and launch your project. Planning a project takes a lot of time. One round of input and revisions may not prove sufficient. A feasibility study may find that alternative options should be considered. This checklist is not linear but rather a circle that goes around and around. Strong projects revisit these steps years after launching to ensure the project is on track to reach the long-term vision, that community support remains strong, and that finances are sustainable. Good luck!

The USDA Forest Service Community Biomass Handbook Volume 1 describes the need for community support, or "social license." Social license is the act of balancing all of the needs of the stakeholders invested in the project, that will be affected by your project. This handbook is a great resource for steps on how to evaluate community capacity, plan for involvement, and engage community members.

"Within the school itself, seeing kids recognize the healthy benefits of eating fruits and vegetables and recognizing that they can do this at home, that this is a life skill that they can carry on through their adult life–that to me is the most rewarding, they want to make their own systems and bring them home. They bring their families in and give them tours of the greenhouse. The engagement between the school, the families, and the community provides a fantastic platform of engaging all those people."
– Megan Fitzpatrick, Teacher,
Southeast Island School District

GETTING TO YES!

- ✓ Long-term vision?
- ✓ Goals? Ranked in order of priority?
- ✓ Short-term objectives laid out in a realistic timeline?
- ✓ Who will act as the project champion?
- ✓ Does the community support the project idea?
- ✓ Have you identified local resources and capacity?

"When schools get together with businesses, and they get together with their community, and they're all working together and there's committees and they're spinning things...kids get an incredible education out of it, and the schools make a little bit of money and they can sustain programs. They can sustain welding programs and be building boats. They can sustain gardens where they're growing food. Otherwise you just curl up and hide in your classroom. Worksheets are fairly cheap, but they sure don't do much for the kids."

– Colter Barnes, Principal, Southeast Island School District

2 PLANNING

PROJECT CONSIDERATIONS

PRECEDING PAGE: Lettuce in an aquaponic system in the Southeast Island School District will go to salad bars in the school cafeterias.

Project goals

After deciding a biomass-heated greenhouse will benefit your community, the next step is to establish project goals. As mentioned in Chapter 1, a project team will set a vision and priorities to define and shape the project. Then, project leaders need to divide the long-term project into a set of short-term objectives to guide actions along the way.

Setting goals is an excellent time to involve the local community: local government, the tribal council, neighbors, school staff, and students. In Alaska, many small rural communities are already accustomed to working together. However, it's important to ask community members about their vision for the community, and how a biomass-heated greenhouse can complement other community goals. This input will strengthen a project vision – if the entire community and local officials feel the project is in line with the community's goals and resources, then community members and organizations will be more likely to support and help with the project.

Vision and priorities

When setting a long-term vision, think in terms of years or decades. It may take that long, or longer, to reach the goal. In the interim, the vision will help guide day-to-day project tasks. Example visions for Alaskan projects may include some of the following components:

Nutritious school lunches: Fresh, local, nutritious produce served in the school cafeteria.
Stable heating costs: Locally-sourced biomass fuel is less subject to price fluctuations than fossil fuels, and can reduce a community's dependency on outside fuel shipments.
Comprehensive education: The opportunity for teachers of all subjects, from biology to electives, to utilize the biomass-heated greenhouse for hands-on projects in their classes.
Profit: Sales of vegetables to local cafeterias, restaurants, and grocery stores may offset operation and maintenance costs.
Food security: Year-round availability of produce supplied to the local community, even when outside shipments are disrupted due to weather or other unforeseen circumstances.
Local jobs: A project that employs members of the local community to operate a biomass appliance, provide biomass fuel, or perform daily greenhouse tasks.

With your long-term vision, establish priorities. Which part of your vision will you pursue first? For instance, a greenhouse may not be profitable in the beginning, or ever, depending on its layout, staffing, and operation. This may be fine for projects with a priority on education and ample funding. However, for projects depending on income from produce sales, profit might be a higher priority.

What are some priorities that make sense for your community? Which rank highest? Every vision starts as a rough draft, to be refined through discussions with the project team, project stakeholders, and community at large.

Lettuce is just starting out in this greenhouse in the Southeast Island School District (SISD). The greenhouses in SISD have significantly impacted the local community. As Megan Fitzpatrick, a SISD teacher, puts it "When your foodshed is smaller and you are eating locally, [the students] are recognizing that money can provide jobs here in the community and the food is more nutritious and it tastes better than when it comes from far away. That is the big impact."

SMART objectives

After establishing a long-term vision, project leaders will need to break down the process into achievable objectives that can be met as the project moves along. It's a good idea to start small and then expand. Each objective should be SMART: Specific, Measurable, Attainable, Realistic, and Time-bound.

The more detail the better when project leaders set these objectives. Who will be in charge of implementing the task and who will help? Where will funding come from? What materials are needed? Where will the task occur?

In setting SMART objectives, keep your community and organization in mind. What local resources are available? What is the realistic first step? As objectives are completed, leaders should seek input from the project team to plan the next objectives.

For example consider a rural Alaskan school that uses a cordwood boiler to provide heat to the school building. School officials know the boiler provides more heat than the school building uses, and want to build a greenhouse to utilize the excess heat. Two example first objectives for this project might be:

Objective 1
Specific objective: Build raised beds for a small outdoor school garden
Measurable: The team will build a set of 8 raised beds, each 12 feet by 4 feet, behind the school next to the future greenhouse location. A local company, Gravel and More, has donated soil to fill the beds.
Assignment: The school science teacher has volunteered to lead this task. She will work with the shop teacher, who will have the students build the beds during shop class. The science teacher will coordinate the building and filling of the beds.
Realistic: The school obtained lumber and soil donations for the beds, and shop students can build, place, and fill the beds during class as a project.
Time: The beds should be built during the fall semester, so that planting can begin in the spring.

Objective 2
Specific objective: Build a storage shed for wood chips.
Measurable: Project team leaders will hire a construction crew to build a large shed to store wood chips. The shed will protect the wood chips from rain and snow, but also allow for airflow so the chips can dry out. The shed will have one open side to allow equipment to enter and deposit or gather wood chips. The three remaining sides will have openings to allow for airflow while still protecting the chips from the weather.
Assignment: The project leader is in charge of advertising a request for proposals for a construction crew. Members of the project committee will meet to review proposals and award a contract.
Realistic: The school district has funds for construction of the shed. The school board, City Council, and Tribal Council all support biomass-heating projects in the community.
Time: The shed should be constructed within six months.

What is the first SMART objectives for your organization as the project team works toward the vision?

Specific objective:

Measurable:

Assignment:

Realistic:

Timeframe:

"Expect 'book work and footwork' in the beginning. It won't be easy. The workload will be heavy. But then in a few years when things are running smoothly due to your careful planning you can pat yourself on the back"
– Sandee Mayo, Lead Administrative Assistant, CCHRC

Operations plan

If the vision defines the project destination, the operation plan describes how to get there. Many organizations will simply call this plan their business plan or strategic plan. No matter what the name, the purpose is to set expectations for the project team and describe how the daily, monthly, and annual tasks.

The project team should draft an operations plan after deciding on a vision and priorities. Funders and stakeholders will want to see the plan to evaluate the project's sustainability. Having a thought-out plan and being open to revision demonstrates a team's capability to start a project and commit to seeing it through.

During the drafting process, schedule presentations of parts of the plan, or the entire plan, to different groups of stakeholders to collect feedback. Listen to comments, criticism, and praise and then revise and strengthen the operations plan. Some groups to present the plan to might include:

- Team members
- Future staff
- Teachers
- Students
- Potential volunteers
- Building staff, such as cooks, janitors, and maintenance crew
- Neighbors
- City council
- Tribal council
- Planning commission
- Community members
- Neighbors
- Leaders and staff of similar projects in the area

An operations plan should be as comprehensive as possible. A team can add details each year as members gain experience and training. Keep the plan where it can be accessed by all team members – a clearly-labeled notebook in the greenhouse can serve as a hard copy, and an electronic copy might be stored on website or server.

Several topics that an operations plan might include are addressed in this handbook, and the resource list at the end of this chapter contains several websites and publications that can help in drafting sections of the plan.

Revision: No plan will be perfect from the first draft. Recognizing the need for continual improvement at the planning stage will set up a team to be ready to refine their plan on a regular basis.

Participation and management: Who makes up the project team? What are the different duties of each team member?

Safety: Safety is not a list of tasks, but an attitude the entire project team must practice and uphold! Addressing safety practices upfront in an operations plan sets the tone for the duration of the project.

Daily operations: Procedures for regular tasks should appear in the operations plan so workers perform them consistently. The Building, Heating, Growing, and Funding chapters address the tasks for each of those topics.

Wood harvest in Tok, Alaska.

> "Every situation is different. In Tok, we had a very specific set of opportunities. You need to take stock of your own local talents, infrastructure, and materials."
> – Scott MacManus, Superintendent, Alaska Gateway School District

Finance: In planning for financing a biomass system and a greenhouse, an operations plan should address capital cost of future improvements as well as the day-to-day maintenance and operating costs. The Economics and Funding chapters have resources that will help define the financing of a project.

Marketing: Do you have a specific group of people in mind, such as the school cafeteria or customers of a local grocery store, which will be purchasing your produce? If not, how will you decide where to sell produce? What are strategies for communicating where the produce comes from? How will you determine the price of your produce? See the Economics chapter for more details.

Data collection and record keeping: How does the project team plan to handle record keeping? Who will be responsible? Collecting notes, data, and records is an important part of any project. Data review will show opportunities for improvement, allow new project members to learn what happened in the past, and provide a connection between workers performing daily tasks, the leadership team, and those paying the bills. See the Building, Heating, Growing, and Economics chapters for ideas on what data to collect.

> "I like the idea of doing something innovative in my community. We are tackling a problem with an innovative solution."
>
> – Will Anderson, Kikiktagruk Inupiat Corporation (KIC)

Kikiktagruk Inupiat Corporation (KIC) installed a unit from Vertical Harvest Hydroponics in Kotzebue. The unit contains a computerized hydroponic system and is heated with a small Toyo stove. KIC installed the unit in May 2016 and first harvested vegetables in June 2016. They currently sell produce to the hotel, hospital, and supermarket.
In Kotzebue, much of the produce comes from California, with a 10 day shipping time. KIC's motivation for the project was to increase food security, provide fresh vegetables, and hire a local part-time employee. Joe Carr, pictured above, currently works around 20 hours each week planting, harvesting, and learning to operate the hydroponic system.

Photo courtesy Kikiktagruk Inupiat Corporation.

Tim Meyers owns Meyers Farm in Bethel, Alaska. He uses greenhouses to start seeds each spring, and high tunnels through the summer for tomatoes and cucumbers. During his years of farming, he has found that Alaskan agriculture has a few unique advantages. The colder climate means he can grow strawberries and cabbage. He also can use the cold ground to store harvested produce in the fall.
Photo courtesy Meyers Farm, Bethel, Alaska.

Revision

Expect to revise your operations plan on a regular basis. Your long-term vision and priorities will likely remain set–after all, they define your project. But the method to reach those goals–the operations plan–will improve as the project team gains experience, as stakeholders and staff provide feedback, and as local resources and capacity change. It takes time to know your own project–a biomass heating system, a greenhouse–and learn the feel of it.

The plan needs to address its own revision with guidelines on how to go about gathering suggestions for changes, reviewing them, and then accepting the ones that make sense for the project. For many, that will look like a two-step process that occurs annually at a time that makes sense for the project team's schedule (probably not during peak harvest season).

1. Gather input
The operations plan should identify the method to be used to collect feedback about how the project is going. Respect everyone's voice and opinion and consider suggestions seriously. Some ways to do this include:
- **Review data:** Now is the time to look at the data that has been recorded throughout the year. For instance, a team might be collecting data on greenhouse conditions, costs, incidents, revenue, general notes, and team meeting minutes. Biomass heating staff will likely note how much biomass is burned and what and when maintenance has been performed. What trends emerge from this data? What should be the same next year and what should change.
- **Staff input:** Staff and other team members (including students) should have a transparent, planned process to provide feedback on how operations are going. This might involve a special team meeting to brainstorm and discuss suggestions, or it may be a form that staff members can submit for project leaders to review.
- **Customers:** If your team is selling vegetables to customers, be sure to solicit feedback from them. This may occur through an informal or formal conversation, or through a formal market survey. What vegetables do they like? Which ones would they want to add? What other requests do they have?
- **Local stakeholders:** The broader community may have ideas for improvement. Again, planning for and providing a method for them to make suggestions and comment will smooth the process for everyone. This could be ongoing–by providing an email address for comments, through fliers, or at an annual open house event.

2. Revise your plan
The project leadership team will meet to discuss input and what can change. Again, doing this annually, or at least on a regular basis, will keep your operations plan up-to-date and relevant.

- **Discuss suggestions:** After reviewing all input, discuss what changes need to be made.
- **Revise operations plan:** Designate an individual to edit the plan.
- **Communicate changes:** Provide your team, stakeholders, and customers with a summary of changes that affect them. Be sure the project team has access to the revised, current operations plan.

Participation and management

Encourage diversity in both management and general participation in your greenhouse project. Beware that too much responsibility on one person is not sustainable or representative of a community project.

Positions

Leadership: Every project needs a champion to maintain momentum. Depending on the size of a project, an individual or members of a steering committee may lead the project. These positions may be formally hired, or project staff may assume them informally as a project evolves. Think about what makes sense for your project and community. If you have the personnel, a leadership committee is a great way to bring together talents. Committee members might include a president, vice president, secretary, treasurer, maintenance coordinator, membership coordinator, and events coordinator. Make sure key stakeholders are represented on a leadership committee or board–staff, community members, students, teachers, volunteers, and even customers or cooks.

Overall management: Management may come from a single individual or a committee. What is right for your project depends on the time and resources at your disposal. Is there a committee of stakeholders who can provide support and input? When preparing the implementation plan, address how the project will be managed, and how managers and committee members will be replaced as needed. It's important to pass down knowledge and practices as leadership changes.

Financial management: Project finances can be thought of in terms of "ins" versus "outs." What does a project need to pay for? These are the "ins"–labor, seeds, equipment, energy, materials. How will a project generate revenue? What is the market for your produce? These are the "outs." The process for buying "ins" should be specified in the operations plan, as well as the procedure for pricing and distributing produce. The plan should specify who is in charge of these tasks and ensure they have the training and support needed to carry them out. Refer to the Economics chapter for more information on the financial management of your project.

Staff: Finding the right number of staff will take some experience. Labor requirements for biomass systems and greenhouses differ widely based on the end goal. For instance, a production greenhouse will require more staffing for growing, harvesting, and processing than one focused on education. Expect to spend one to three years finding the right balance. In addition to specifying positions and responsibilities, the operations plan should address how staff will be trained and recruited and how to preserve institutional knowledge when staff members leave. Also, how will the team handle days when key staff are sick or on vacation? Biomass systems and greenhouses require constant care, so it's good to have a system in place to ensure that the buildings stay heated and plants are watered.

Volunteers: Many projects may rely on volunteers to complete some or many tasks, a great way to increase community involvement and capacity. To make sure volunteers feel valued, specify training procedures in the operations plan and be ready to revise them based on input. Compensation is important, especially if volunteers are working side-by-side with paid staff. Some ideas for rewarding volunteers are to offer access to discounted produce, provide training or certification, and recognize volunteers at an annual harvest party or in a newsletter.

Stakeholders: Seek input from all project stakeholders and incorporate it in your operations plan. If you will be utilizing volunteers, ask what they feel a reasonable shift would look like. If your greenhouse is at a school, talk to teachers about how they could use it and what resources they need. If you will be providing vegetables to a cafeteria, make sure cooks are happy with the quality of produce and mix of offerings.

"We have all of the 'hardware' in the world, but we don't currently have the 'software' (people, personnel) to support it successfully. Make sure you are willing to invest in that and I think the results will speak for themselves."
- Colter Barnes, Principal, Southeast Island School District

Enthusiasm

Expect to grow enthusiasm along with your plants! It also requires cultivation among all parties.

Open communication: Encourage communication among the project team. This means that leaders should be open to talking about a project when concerns or comments arise and that there should be built-in procedures for stakeholders to provide input. Consider regular surveys, a comment box, an email address for feedback, or staff meetings.

Staff and stakeholder meetings: Take the time to plan and hold meetings. An annual staff orientation will start everyone on the same page each year; monthly safety meetings give staff a set forum to reflect on daily procedures. Similarly, holding an annual meeting, open to the community, will allow all stakeholders to see the project first-hand. Combining it with an annual harvest party also might facilitate some vegetable sales. Finally, some project leaders take time to visit community stakeholders in person to talk about project goals and listen to feedback.

Training: Allow staff, students, and volunteers to gain skills through training. This might be safety training on pesticides, or more comprehensive courses on gardening. The University of Alaska Fairbanks Cooperative Extension Service offers courses in Alaska on these topics and others. More resources are listed at the end of this chapter. There are conferences held in Alaska each year, including those from the Sustainable Agriculture Resource Education (SARE) and the Alaska Farm Bureau Inc. For biomass projects, the Rural Energy Conference and the Alaska Wood Energy Conference provide regular opportunities to learn about heating with biomass. Not only do these conferences often provide training, attendees have a chance to network with others in similar industries, brainstorm solutions to common issues, and advertise their project.

When Don Berberich, a teacher at Palmer High School, started his greenhouse class, he went to all commercial greenhouses in the area and told them he was training people to work or buy from them. This helped with relations between them so the school wasn't seen as competition. The greenhouses have even donated specific sizes of containers and an automatic seeder to the program. Photo courtesy Palmer High School.

Safety

Safety is an ongoing priority of every project – safety of staff, consumers, students, volunteers, and all other participants. Two of the largest safety components to a biomass-heated greenhouse project are food safety–ensuring that produce from the greenhouse will not make anyone sick–and workplace safety–ensuring that staff, volunteers, and students in and around a greenhouse or biomass heating appliance are not injured. However, constant observation and safe practices should dominate all aspects of a project. Safety should be addressed from the very early planning stages to the time people are enjoying a meal made from local produce.

Food safety

The two most important aspects to food safety are **GOOD HYGIENE** and **CLEAN WATER**. Of course, this section will discuss many more components to a food safety plan, but focusing on healthy habits such as hand washing and clean water will go a long way toward ensuring the production of safe food.

Good hygiene: First and foremost, this means washing hands. Workers should wash hands before work, between tasks, and after using the restroom. Proper hand washing includes lots of soap and water, washing for at least 20 seconds, cleaning under fingernails and between fingers, and using a single-use towel for drying. Hand washing facilities should be easy to access in the greenhouse. Other examples of good hygiene include NOT eating, chewing gum, using tobacco around plants, or working when sick. A water fountain is recommended for drinking water.

Clean water: If you wouldn't drink it, then you shouldn't water your lettuce with it. Municipal water supplies can be used for watering plants; other water sources may require regular testing to ensure the water is clean enough to be used on ready-to-eat plants such as lettuce. In a recirculating hydroponic system, the water should be regularly tested for contaminants. The water used to process produce should also be potable.

Food safety encompasses many other components besides these first two. It's important to incorporate these practices into daily routine so that food safety it not an isolated practice. A Good Agricultural Practices (GAP) audit, which may be required by the buyer of your produce, is the most comprehensive resource on food safety for agricultural businesses. Auditors are aware of food safety regulations and any recent changes, and are skilled in identifying and demonstrating safe practices to workplace employees. Additionally, committing to a regular GAP audit demonstrates a commitment to safety to your staff, buyers, and community. These audits, available from the Alaska Division of Agriculture, do require upfront payment. There are ways to lower costs, such as by arranging an audit in conjunction with other area growers or asking a buyer to share the cost.

The 2011 United States Food Safety Modernization Act, which was the first update of food safety policy in America in more than 70 years, is another resource on food safety. While many projects will be exempt from these rules (if you sell less than $25,000 of produce annually or if the product is sold within 270 miles of where it was grown), they still provide helpful guidelines.

Students and staff plant seeds in a biomass-heated greenhouse in the Southeast Island School District. It is important to wash hands before and after working in a greenhouse.

Additional considerations listed here provide a good starting point for a biomass-heated greenhouse:

Building design: A safe workplace begins before the first seeds are planted. Is the building designed with safety in mind? For instance, can pesticides be stored away from harvested produce? Do workers have a break area nearby? Have the soil and water been tested for contaminants before planting begins? Does the room with the biomass appliance have adequate ventilation? Are shelves stable and within reach? Are fire exits clear? Planning for regular evaluations of safe practices, and for safety training, will keep safety at the forefront.

Record-keeping: Keeping records of safety practices, such as training, cleaning tasks, and incidents, serves several purposes. First, it helps project leaders evaluate how things are going– if trainings are happening as planned, if procedures are being followed, and why incidents have occurred. Records are also useful for audits and help everyone involved with the project stay on the same page. If a new leader or staff member joins the process, they can quickly see what safety practices are in place.

Training: Regular training should be available for all employees, including orientation for new staff by a supervisor or team member. All staff should undergo training to learn new safety practices and refresh old ones. Such training might consist of attending a formal workshop or conference or monthly staff meetings to discuss a specific procedure. The key to training is to provide regular opportunities for all staff to communicate new ideas, learn safety skills, and refresh skills.

Designated break area: Provide staff with a restroom and designated break area, either in the building or one nearby, for phone calls, drinking, eating, and personal time. Such an area keeps food and drinks from spilling in areas with crops, and personal items such as backpacks from becoming a tripping hazard near a biomass appliance.

Regular cleaning and maintenance: The greenhouse, biomass appliance, and their systems need to be cleaned on a regular basis specified in the operations plan. The tasks will differ for each biomass appliance and greenhouse, but could include cleaning the firebox, sweeping the floor, cleaning windows, sanitizing harvesting equipment, and changing filters. Regular cleaning is especially important in the processing area: equipment, surfaces, and storage facilities need to be sanitized on a regular basis.

Organization, labels, and signs: An organized workplace is easier to keep clean, and also helps ensure proper equipment is on hand for all tasks. Make sure storage areas are organized and clean. Containers should be labeled so staff do not mix those used for harvesting with those used for pesticides. Harvested and packaged produce should be labeled with harvest date and location, so produce harvested first is delivered to consumers first. Signs in easy-to-see locations remind staff of proper procedures for each task, reinforce safe behaviors, and set the tone for new staff.

Greenhouse storage at the University of Alaska Fairbanks research greenhouse is clean, well-organized, and labeled.

Safety is contagious. It can be "taught" certainly, but also "caught" when everyone has the proper attitude and practices. (California Agricultural Teachers Association, 2007)

Workplace safety

Workplace safety is an ongoing process that relies on policies and practices that promote safety in day-to-day operations.

BC Landscape & Nursery Association lists 8 components of a health and safety program in its 2012 manual on [Health and Safety for Nurseries and Greenhouses] that are a great starting point for biomass-heated greenhouse projects. Read through these practices and customize them to fit your project.

Identify and minimize hazards: As you set up a biomass system or build a greenhouse, think about how potential hazards can be minimized. For instance, where can you store tools such as axes for chopping firewood so they can only be accessed by trained staff? Similarly, if you are planning to use chemical fertilizers, how can they be stored safely? Where will Safety Data Sheets for chemicals be available? Ask for people with experience in similar projects to do a walk-through of your building and offer tips–and ask your own staff for input on existing hazards. Focus on prevention when thinking about safe practices.

Safe work procedures: First, train workers on how to approach every procedure with safety in mind, and general safe work practices such as avoiding horseplay and keeping a clean workspace. Identify who is responsible for which components: teachers, students, staff. Some procedures should have written steps, lists of hazards, and actions that can be taken to minimize risk. Written steps should be posted where they will be easily seen by whoever is completing that procedure. To decide which tasks require a write-up, think about how often the task is done, how complex it is, and how severe a potential accident could be. Consult the umbrella organization, such as the school district, and others involved when writing the procedures, including maintenance staff, future workers or volunteers, and supervisors.

Orientation, education, training, and supervision: All of these help workers to follow safe work procedures and approach all tasks with a safe attitude. Especially important for new workers, orientation can be as simple as a walkthrough pointing out potential hazards and safety features on an employee's first day. Topics should also include the rights and responsibilities of the worker regarding safety. Having staff read and sign a safety contract after training helps to stress the importance of safety. Follow-up discussions are important.

Safety inspections at regular intervals: Regular safety inspections, both in-house and third-party, ensure safety hazards occurs are addressed on an ongoing basis. It's helpful to develop an inspection checklist and combine observations of the workplace with conversations with staff to identify potential hazards. Then follow up with solutions to minimize hazards and communicate new practices and procedures to the team.

Incident investigation: When safety incidents do occur, use them as teaching moments to learn and improve workplace safety. Arrange an investigation to determine cause and find ways to prevent similar incidents. Ask questions. And finally, formally document the incident so anyone doing a future annual review or audit also learns from what happened.

Regulations usually require acid to be stored in a separate cabinet away from bases and other solutions to prevent accidental contamination and potential hazardous situations. In a school environment, it may also be required that hazardous materials be locked up. Ensure flammable materials are in a heat-resistant cabinet that can be secured.

Health and safety meetings for entire team: Set a regular date and time, such as monthly or bi-monthly, for the entire team to meet and discuss safety. Meetings should have an agenda to keep focus and can discuss prior trainings, worker observations, and active concerns. Keep a record of these meetings and be sure to follow up on any points that require action.

First aid kit: A well-stocked first aid kit needs to be readily available. All workers should be trained on where it is and how to use it. They should also know what to do in the case that the first aid kit is not adequate to address an incident. The first aid kit is also a great location to post procedures for emergencies such as fire, earthquake, or evacuation.

Keep records and statistics: Records are critical. They can be used to identify beneficial practices and recurring problems that need to be corrected. New employees can refer to them to orient to practices. Auditors can use them to evaluate practices and suggest improvements. It's important to find a record-keeping system that works for your team, is accessible to all project staff, and is easy to use. Safety records include training activities, first aid treatments, incident reports, inspections, and monthly meeting notes.

Floor drains can help prevent slipping hazards, algae growth, and other safety issues.

Insurance

Whether or not a project needs insurance, and what types of insurance are needed, will be influenced by three main factors. First, if the greenhouse is producing vegetables for sale, many buyers have policies in place that require growers to meet a certain threshold of liability insurance. Buyers, especially larger ones, may also have requirements on how often audits need to occur, and how often workers will need safety training.

Second, if the biomass-heated greenhouse project is occurring under the umbrella of a larger organization such as a school district, the organization may have insurance, training, and audit requirements. The existing insurance policy can usually be expanded to cover the greenhouse and biomass projects and the project team will not have to search for a new policy. However, it's important to check with the insurance company to make sure that they cover the wood-burning appliance and greenhouse.

Finally, there are also government requirements on insurance, covered in the Food Safety Modernization Act (FSMA). These requirements will not apply to every greenhouse project, as smaller farms (those with an average annual value of produce less than $25,000) are exempt. However, exempt projects will still need to have paperwork on hand proving they are exempt.

Past those three inputs, it is up to project leadership to determine insurance, and what types they need. Insurance can cover a variety of different aspects to biomass and agricultural projects, including general liability, buildings, crops, and worker's compensation. For projects thinking about obtaining insurance, some good resources include:

The umbrella organization: As mentioned above, the larger organization (such as a school district) may have an existing insurance policy and an established relationship with an agent. Insurance for the project may be added under the existing policy.

Local farms/biomass-operators: Ask what type of insurance similar projects have in your area, and where they get it. They may have valuable experience and advice.

Insurance agents: Shop around when searching for insurance and get multiple quotes. Look for good value and good customer service. Agents should be able to present your project team with different insurance options and their recommendations. Insurance companies may also be able to provide resources for your project, such as volunteer waiver forms, photo permission slips, and incident report forms. Ask different agents how they can support your project when you are searching for a policy.

Resources

Vision and priorities:

USDA Community Food Systems: Toolkits for starting a farm to school program and evaluating current programs.

Implementation plan:

Local business classes: Is there a college or school in your town with business classes? Talk to the instructor, students may want to take on your project for a class assignment.

State of Alaska Department of Commerce, Community, and Economic Development Small Business Assistance Center: Resources on marketing, financing, business licenses, and more.

The Foraker Group: Resources for Alaskan nonprofits on strategic planning, financial planning, organizational development, human resources and more.

University of Alaska Small Business Development Center: Tools for every stage of business development, from starting up to revision.

University of Alaska Cooperative Extension Service: Small business and economic development resources on writing a business plan, leadership, and record keeping.

Food safety:

Alaska Division of Environmental Health Food Safety & Sanitation Program: This website contains resources on food worker training, safety rules, frequently asked questions, and more.

Alaska School Garden Food Safety Guidelines: This publication is by the Alaska Department of Natural Resources, Division of Agriculture, Inspection Services & Farm to School Program. It provides guidelines on a number of topics relevant to greenhouses - personal hygiene, soil treatment, planting, water treatment, harvesting, and more. It also includes a weekly checklist and sample food safety signs.

Food Safety Modernization Act: Key facts and standards for growing produce for human consumption.

Food Safety News: The latest news to learn about what is new in food safety.

GAP audits: To learn more about audits or to schedule one, contact the Alaska Division of Agriculture.

On-Farm Food Safety Plan: Education and tools to create a personalized food safety plan.

USDA Community Food Systems: Videos, fact sheets, presentations and webinars on food safety.

Workplace/school safety:

American Red Cross: Check to see if they offer first aid training in your area.

California Agricultural Teachers' Essential Guide to Safety: In addition to information on legal requirements, managing health and safety, and hazardous materials, it contains several practical resources such as a sample letter to parents, a sample student incident report, and facility checklists.

Flinn Scientific: They offer lab safety courses for teachers, and resources on safety demonstrations, safety contracts, and Safety Data Sheets.

Health and Safety for Greenhouses and Nurseries: This publication is done by WorkSafeBC, and similar to the California Agricultural Teachers' Essential Guide to Safety, covers topics such as hazard identification, first aid, crew safety talks, and equipment safety in addition to containing sample forms and checklists that can be used for a workplace safety plan.

National Science Teachers Association: Their safety webpage contains information on storing chemicals, safety in the classroom and laboratory, and safety contracts.

University of Alaska Fairbanks Cooperative Extension Services: Information on pest management and pesticide safety education.

United States Department of Labor Occupational Safety and Health Administration: Has pages on hazard communication (including Safety Data Sheets) and guidelines for agricultural workers.

3 BUILDING

DESIGN AND CONSTRUCTION OF THE COLD CLIMATE GREENHOUSE

PRECEDING PAGE The greenhouse at Howard Valentine Coffman Cove School on Prince of Wales Island, just after construction.

After planning is completed, it's time to think about building. Designing and planning the greenhouse building will be one of the largest steps towards bringing your project to operation. There is a lot to think about when considering greenhouse construction. This chapter is meant to give project teams a basic understanding of the options that exist for different materials, designs, and systems in a greenhouse. The chapter begins with guiding principles to consider when deciding on location and design, and then reviews options for building materials and mechanical systems. Teams will have to decide on what makes sense for their own goals and resources – which could include anything from purchasing a greenhouse kit from a manufacturer and hiring an outside contractor to install it, or building the greenhouse from local materials and with a local crew.

"Greenhouses are prime real estate. They are Park Avenue in the game of monopoly."
- Tom Zimmer, Calypso Farm and Ecology Center

Guiding principles

Choosing a location and constructing the greenhouse involves many decisions! Your team will likely have to compromise on certain aspects in order to take advantage of others. Here are some factors to guide decisions as your team makes a specific plan for building the greenhouse.

Location: For biomass-heated greenhouses, there are many considerations as to where to place the greenhouse. First, where is the biomass appliance (or where will it be located, if not already in existence)? Will other buildings also be heated using the biomass appliance? Consider the cost and logistics of moving heating from the biomass appliance to the greenhouse and other buildings – shorter distances between the biomass heat source and the buildings mean less piping to purchase and install, less heat loss, and smaller pumps. Of course, your team will also want to consider location variables specific to the greenhouse itself. If possible, choose a location that has limited shading from buildings, trees, or other obstacles by observing sun patterns over the various seasons. Other factors to consider include prevailing winds, topography, access to water and utilities, space for renovation or future expansions, anticipated use of surrounding land areas, and ease of entry for deliveries and customers.

Direction and placement: Design professionals recommend placing standalone greenhouses with the long axis oriented east-to-west in order to maximize solar input for plant growth. However, it's also recommended to place the short end of a greenhouse toward the prevailing wind to reduce cold season heat loss, wind damage, and snow accumulation. Sometimes the best orientation for wind and solar exposure will line up, but this should not be expected. If needed, a windbreak placed upwind of the prevailing wind direction can help achieve some of these benefits. Winter sun angles are relatively shallow in Alaska, so don't let a windbreak also serve as a sun blocker. Another placement consideration is how your team will access the greenhouse with equipment. Will staff be transporting produce to a local restaurant by truck? If so, can the truck drive up to the greenhouse? Will the greenhouse crew need to purchase fertilizer and soil for a growing system? How will these materials be delivered?

Greenhouses attached to a heated building are more efficient because they share a common wall, such as the greenhouse at the University of Alaska Fairbanks School of Natural Resources and Extension. Access and hookup to water, heat, and electricity may be easier and more straightforward for attached greenhouses than for separate, freestanding greenhouses. This greenhouse is also "gutter-connected," with the greenhouses in the forefront connected at the gutters. Gutter-connected greenhouses increase energy efficiency by decreasing the outside surface area of the building.

3 BUILDING
DESIGN AND CONSTRUCTION OF THE COLD CLIMATE GREENHOUSE

Greenhouses in cold climates and high latitudes must account for unique factors such as snow loads, low sun angles, and cold temperatures during the winter season. All greenhouse designs should be appropriate for the location.

Examples of greenhouse packages and kit suppliers used in Alaska:
Stuppy Greenhouses
Gothic Arch Greenhouses
Agratech Greenhouses
Nexus Greenhouse Systems

Visit the University of Wisconsin website for more kit suppliers

Construction: The greenhouse can be freestanding, attached to another building, or gutter-connected (several greenhouses connected together at the gutter). Since limited natural light will enter the greenhouse on the north side, this is the side that is typically attached to another building. Similarly, freestanding structures often have an insulated solid north wall. The north wall also might be a good place to partition work areas, storage, break rooms, and bathrooms. Greenhouses need these features so the greenhouse interior can be dedicated to growing plants.

Structure and design: What are challenges and opportunities presented by the local climate? Locations with high snow loads should take this into account when considering a greenhouse design. A shape that can shed snow will prevent collapse in areas with substantial snowfall. Is there a prevailing wind? If possible, orient the greenhouse so the wind will work with the ventilation system. Also, who will be building the greenhouse? If you are planning to hire a local crew, what local materials can they utilize, and what designs do they have experience with? Greenhouse frames can be wood, metal pipe, or aluminum. The frames can be shaped into a gothic arch, A-frame, or hoop design. A peaked roof sheds snow and inside water condensate more efficiently. All of these designs can be used in a gutter-connected greenhouse as well. The limited outside wall surface area makes gutter-connected greenhouses more energy efficient than free-standing structures. However, in areas in Alaska with high snow loads, the building might require a heat source in the gutters to thaw snow, and drains to divert melted water away from the foundation.

Covering materials: Glass has often been used as the greenhouse covering material because of it high light transmission and long life expectancy. However, it is often more expensive and difficult to install than plastic alternatives because of its weight and fragile nature. Common alternatives include double-walled rigid plastic panels of acrylic or polycarbonate. For seasonal and temporary structures, polyethylene film is a common choice. For heated structures, two layers of polyethylene film are typically installed and held apart by a low positive air pressure. The air-inflated double layer polyethylene film reduces fuel consumption by about 40% compared to a single layer polyethylene film greenhouse.

Production systems: The intended production system is another design element to consider. Will plants be placed on tables or grown in a hydroponic system? Crops like tomatoes require trellising and a greenhouse tall enough to accommodate the growth. If hanging plants or baskets will be used, support systems and structural greenhouse strength need to be considered. In yet other systems, plants may be grown on the floor.

Sizing: Project goals, funding opportunities, and available resources should determine the size of a greenhouse. When in doubt, small and simple is usually the best way to start, although it might be wise to leave room for expansion. If students and volunteers are allowed to take produce home, it can generate more interest and community support. Planning for some extra plants and produce can therefore be valuable outreach tools.

Greenhouse manufacturers: A variety of greenhouse structures are commercially available in pre-designed packages or kits. Manufacturers consider typical greenhouse standards for structural loads and other design elements, and then customize kits for particular geographic locations. The kit typically includes the construction materials, supplies, and components to meet the standards and requirements for a particular type of greenhouse and location. Using a greenhouse kit can simplify the planning and construction process. Communicating with the kit manufacturer is critical to ensure the greenhouse is appropriate for the climate and other local conditions.

Energy efficiency: When designing a heated greenhouse, energy efficiency is a critical element. Heating makes up an estimated 70–80% of the energy budget of a greenhouse. Electricity makes up roughly 10–15%, and the rest goes toward transportation fuels. Clearly, a greenhouse that is well-insulated, airtight, and optimized for light transmission will be easier and more affordable to operate. But remember there are trade-offs between the needs of the plants and the value of energy efficiency. For example, more layers of covering material in the greenhouse roof and walls means a better insulated structure but less sunlight will be available to the plants, translating into a longer time for plants to grow or more supplemental lighting.

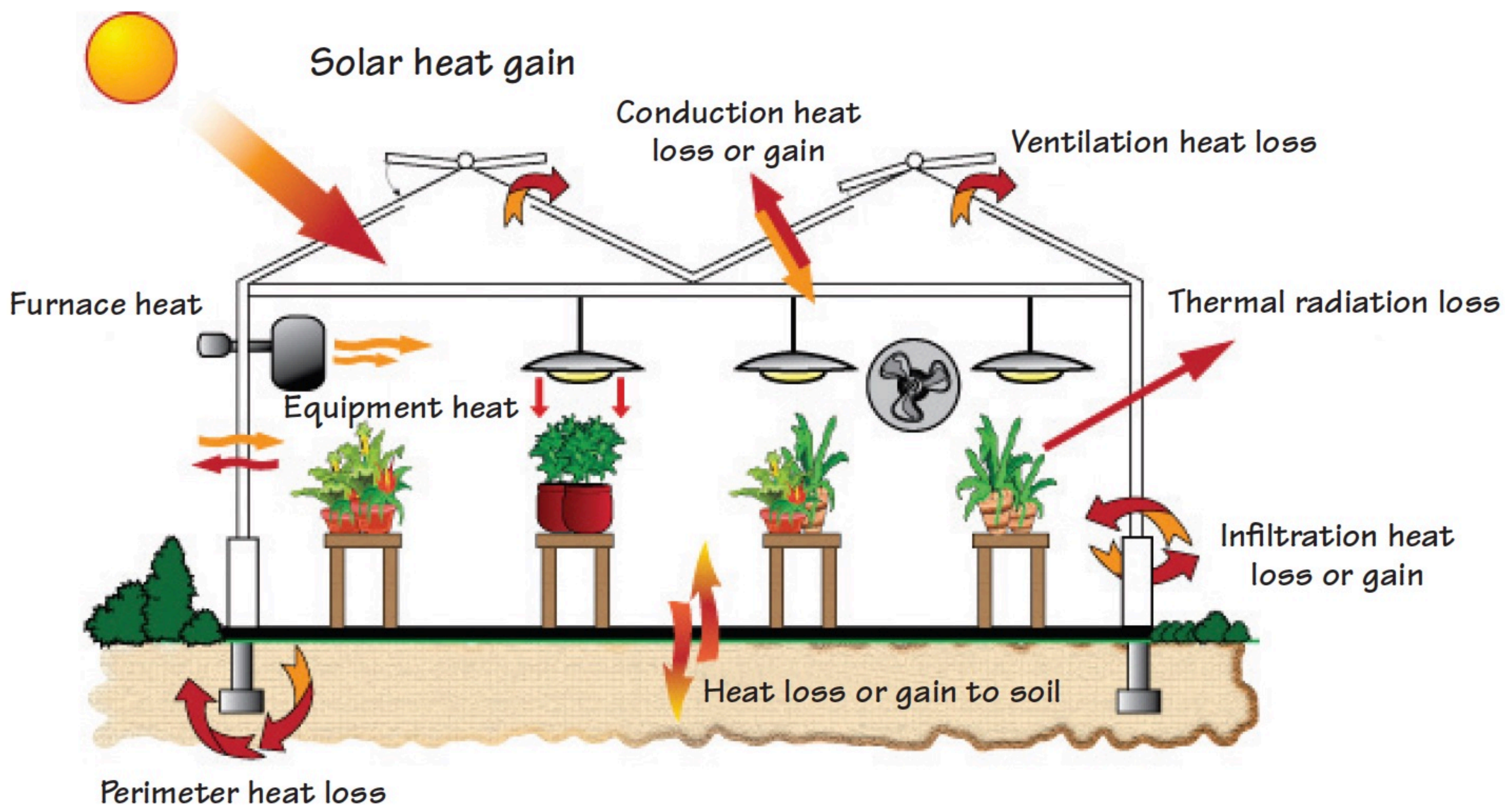
There is also a trade-off between the cost of energy efficient features during construction, and the cost of heating the structure later on. How expensive is your heat? The heat load of the greenhouse will be determined by how large the greenhouse is, the amount of insulation, and the air tightness of the structure. Projects with a large amount of inexpensive heat available from a biomass appliance may not want to spend valuable capital funding on reducing heat load. On the other hand, teams facing a high cost of heating later on, or a limited availability of heat, should carefully consider how big the greenhouse will be and what efficient features it should have. Also, will your team be operating the greenhouse year-round? The cost of heat and lighting in the coldest months of winter may mean that shutting the greenhouse down is a cost-effective strategy.

Building permits: Alaska does not have a statewide building code. However, many cities and municipalities have their own local codes, and these vary in how they treat greenhouses. For instance, some codes have specific requirements for agricultural buildings, and others do not. It's important to call your local planning office when planning to build any structure. Find out what is required in terms of a building permit and inspections. Projects constructing a larger structure meant to be occupied by several staff and students should also consult the local fire marshal. Finally, many organizations that provide funding may have building code requirements for structures built using loan financing or a grant. In areas with no local building code, it's still a good idea to build to the United States national code standards, which are written to ensure buildings are safe to occupy and build.

Devta Khalsa, a project champion for a biomass-heated greenhouse project in Tanana, offers this advice for those just starting a similar project:

1. Do a feasibility study before making a binding decision. Projects of this size need to be fully planned and then built in phases if need be.
2. Start with a complete design so the team knows where the project is headed.
3. Recycle as many materials as possible.
4. Be innovative!

TOP: A metal-framed A-frame greenhouse in Dry Creek, Alaska.
BOTTOM: A wood-frame gothic arch greenhouse on Prince of Wales Island.
Different frame materials and designs have different advantages - choose the one that is right for the resources and goals of your project.



This figure, from the University of Wisconsin Cooperative Extension publication on reducing greenhouse energy consumption, details the many paths that heat can enter or leave a greenhouse. Even in Alaska's cold climate, greenhouses need to be designed both with heating and cooling the interior in mind.

In the winter, heat is lost through the floor, walls, and roof. Heat might be provided from a dedicated heating appliance, such as a biomass appliance. Heat can also come from equipment, lighting, and thermal mass.

In the summer, heat is gained through the walls. The greenhouse might need ventilation to keep it at an optimum temperature for plant growth. In that case, windows and fans can exhaust hot air and bring cool air in.

Building envelope

The building envelope is what separates the outside from the inside of the greenhouse. There are lots of materials to choose from in building a greenhouse, each with its own advantages and disadvantages. For a biomass-heated greenhouse, think about how each decision will affect your future staff. How much maintenance does that material require? Does the building crew have experience with that material or design? How will the feature affect the heat load of the greenhouse, and thus the cost to heat the building?

Frames: Metal frames, made from aluminum or steel, are the standard for greenhouses. Generally, galvanized steel will be less expensive but slightly more susceptible to corrosion damage. Metal frames allow for wider framing spans than wood or plastic, providing less obstruction of solar input and wide entryways for heavy equipment. Wood framing is commonly used for site-built greenhouses, but wood-frame greenhouse kits are also available. Some species of wood frames are susceptible to moisture damage and require more maintenance. If using preservative-treated wood in a greenhouse, make sure the design does not place this wood in contact with soil used for growing plants because the wood preservatives can leach into the soil.

Foundation: As with any structure in a cold climate, the foundation is very important. Unheated structures often rest directly on the ground, but heated and permanent structures should have an insulated foundation that extends below the seasonal frost line, such as concrete footers. A well-insulated foundation reduces heat loss from the building and protects the frozen soil in the winter. Common insulation techniques include adding foam insulation boards vertically around the foundation perimeter or horizontally around the exterior of the foundation perimeter near the footing level. It's best not to build a greenhouse on permafrost. If you do, consider a foundation that separates the structure from the ground completely – such as driven pilings that lift the greenhouse off the ground and provide a thermal break between the heated interior and frozen soil.

The greenhouse interior floor can be a poured concrete slab, gravel bed with walkways, organic material like soil covered with landscaping materials, or a mixture of these options. Concrete is the easiest to clean, but likely the most expensive. On the other hand, organic materials are inexpensive, but might allow pests to become a problem.

Impermeable floors should slope to drains, and drains should have traps to avoid becoming clogged with soil. Foundations need to be kept dry, so drains and gutters should be designed and maintained to keep water away from the foundation.

Covering material, walls, and roof: The main types of covering materials used in greenhouses include glass, polycarbonate and acrylic sheeting, and polyethylene film. Glass has the highest light transmission and has traditionally been the covering material of choice. Glass is usually an expensive choice and requires a structure strong enough to support the weight. Many plastic materials such as acrylic or polycarbonate have replaced glass as a covering material because of cost, ease of handling, and installation.

Acrylic and polycarbonate plastics provide covering options with long life expectancy and good light transmission. Polycarbonate can be expected to last for 10 to 20 years while acrylic can extend to 30 years. Light transmission may be higher for acrylic although improvements have been made in both types to rival the transmission of glass.

Polyethylene film is the least expensive option but may only last a few seasons. The material is light with fewer requirements for a particular type of structure. Since it is a flexible material it can more easily be adjusted to various types of greenhouse designs. It has limited strength and is more vulnerable to damage from snow or wind loads.

Fiberglass reinforced plastic used to be a popular greenhouse covering material. The rapid decrease in light transmission and the availability of better options have decreased its use in greenhouses. Since fiberglass reinforced plastic is often available locally, it can still be an alternative for temporary use and structures.

Reducing heat loss: Since heat loss is dependent on the exposed surface area, greenhouses that are attached to a building, have a solid north wall, or are connected to gutters can be expected to be more energy efficient. A non-transparent solid 2- to 3-foot tall curtain-, knee- or pony wall at the lower portion of the greenhouse can also reduce heat loss, although it does also reduce light transmission at the floor level. Greenhouses in the north often use a double layer of the transparent covering material to increase insulation value. Double layer polycarbonate, acrylic, or glass panels are commercially available and the air in between the layers provides the insulating property. Most greenhouses covered with polyethylene film also use an air-inflated system. A double layer of the plastic film is installed on the greenhouse and a small fan maintains air between the two sheets. Air-inflated polyethylene film tends to have longer life expectancy than a single layer. Some reduction in light transmission can expected with double layer systems but is usually outweighed by the increased insulation.

This greenhouse at the Dry Creek Community in Alaska is not used in the winter. The community utilizes a biomass boiler to heat the interior of the greenhouse each spring as the staff begin planting. In the summer, the boiler is turned off and the greenhouse is cooled using vents on the top and side of the building. On the hottest days, staff use a hand mister to cool the plants.

Thermal mass: Some greenhouses use materials with thermal mass, such as concrete blocks, water in barrels, or rocks, to absorb more heat. The thermal mass heats up with solar radiation during the day, and then releases the heat when the temperature in the greenhouse falls. Some greenhouse designers, such as Bob Sharp located in Whitehorse, use fans and plastic piping to move air through the thermal mass (in his case, rocks under raised beds). The air spreads the heat through the greenhouse interior. Thermal mass helps greenhouses maintain a steady temperature, but on the flip side, also mean that the greenhouse takes longer to heat up if it does get cold.

Thermal screen insulation: Although greenhouse covering materials have been improved, the insulation value remains low in comparison to materials commonly used in other types of buildings. There is always a trade-off between light transmission and thermal properties. To reduce up to 30 to 50% of heat loss during the night, thermal screens, blankets or curtains are available that can be drawn across the greenhouse. The thermal screens can often also serve as a shade to screen sunlight during the day to reduce incoming heat load and cooling requirements for the greenhouse.

When the thermal screen is drawn at night, a smaller volume of air needs to be heated. The screen also reduces convection to maintain the warmer air around the plants. Many types of materials have been developed for use in thermal screens. Polyethylene plastic film may be used, but it is desirable the material is sufficiently porous to avoid condensation while still function as a screen between air volumes. If the material is used for both thermal and solar screening, the curtain is usually some combination of polyester cloth and aluminized film strips. For the most efficient use of screens and curtains, they need to be automated, although having a manual back-up is a good idea for times when the power is out. Several companies offer screening materials and movable screen systems that may be installed and controlled in various types of greenhouses and production systems. Movable thermal curtains can be expected to have a life expectancy of 8 to 12 years.

It's important to open curtains slowly, since the air on the outside of the curtain might be much colder than the interior of the greenhouses. A typical strategy is to wait until the air above the curtain has warmed up slightly, and then to open the curtain partially to allow slow mixing of the air. This prevents cold air from chilling plants.

Design your greenhouse to keep plants alive on the coldest winter day that the greenhouse will operate. You don't want to have your plants die on the one day it gets too cold.

Design your ventilation to keep plants alive on the hottest summer day that the greenhouse will operate. You don't want to have your plants die the one day it gets too hot.

The C-GRO unit in Glennallen is completely insulated and has no windows. While this cuts down on heat loss, it means the plants rely entirely on LED lights to grow.
Photo courtesy Copper Valley Development Association.

Ventilation and airflow

Greenhouses need ventilation primarily to maintain an optimum growing environment. Warm and humid air is replaced by cooler and usually drier outside air. Ventilation can occur through natural design features, or the greenhouse might have a mechanical ventilation system. In choosing between the two systems, think about the goals of the greenhouse, future staff, and the cost and reliability of electricity in your area.

Natural or passive ventilation relies on the concept that warm air rises and is removed by outside winds. Strategically designed and placed vents are needed for natural ventilation to work well. Window vents are commonly motorized and automated to open and close. They can be designed with a manual override feature so they can still be opened and closed in a power outage. Compared to mechanical ventilation, natural ventilation requires significantly less electricity but is less efficient on warm days with limited wind velocity.

Mechanical ventilation requires exhaust fans and air inlet openings in the greenhouse covering. The exhaust fans and inlet openings are usually installed in opposite end walls to move air along the length of the greenhouse. Avoid placing fans in walls against the prevailing wind as air exhausted downwind is more effectively removed from the greenhouse. Multiple and staged fans with variable ventilation rates adjust more precisely to the demand for ventilation. When designed properly, mechanical ventilation maintains good cooling and greenhouse temperatures under a wide range of conditions.

Ventilation openings and fans should be covered with insect screens to reduce potential entry of insect pests. Insect screens add resistance to the airflow and needs to be considered in the design of the ventilation system. Besides ventilation, shade curtains and fogging (misting) systems can be used to cool the greenhouse. During sunny days, the shade is drawn to exclude some of the light and reduce the need for ventilation. Despite lowering the light level, the more moderate temperature will still improve plant growth. A shade curtain often serves as an energy curtain during the night to reduce heating requirements. Fogging cools the air through evaporation of fine water droplets. As heat from the air (sensible heat) is transferred into latent heat of the water vapor, the air temperature drops.

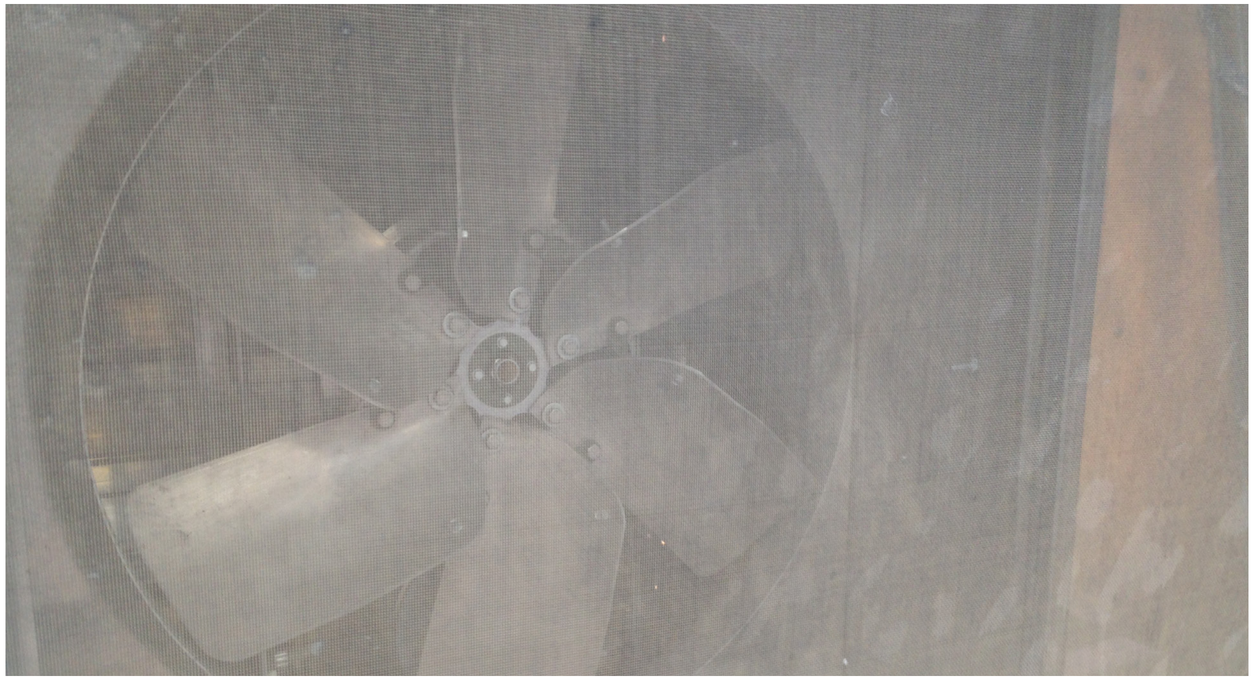
Even during cold winter days, the greenhouse may need ventilation because of the greenhouse effect. Precautions are needed as cold outside air can cause damage if it comes in direct contact with plants. Fans that mix and temper cold air before it enters the greenhouse are therefore used for winter ventilation in colder climates.

Horizontal airflow fans are used to mix the greenhouse air. This is needed to ensure better uniformity of temperature, humidity, and carbon dioxide. In greenhouses with limited horizontal airflow, plant growth is often uneven and slower. In each greenhouse section, horizontal airflow fans are installed from the ceiling in opposite ends to create horizontal movement of air. The required airflow capacity is considerably lower (3 cubic feet per minute per square foot) than for fans used for ventilation (10 to 12 cubic feet per minute per square foot).

When designing the greenhouse ventilation system, again consider how expensive electricity is in your area. Energy efficient fans for mechanical ventilation may be well worth the extra cost in locations with a high price of electricity. Also, if power outages are common, make sure that systems have a manual override. Staff should be able to open windows to cool the greenhouse even during a power outage so plants don't get too hot and die.

"Moving air strengthens plants, gets rid of excess heat, and promotes wind pollination."

- Steve Brown, University of Alaska Fairbanks Cooperative Extension Service



Ventilation fans should have insect screens to prevent pests from entering the greenhouse.

Most greenhouses in Alaska use a combination of natural and supplemental lighting depending on the climate, growing season, and goals of the project.

Lighting

Not all greenhouses have supplemental lighting. However, supplemental lighting can reduce growing times, increase plant quality, and help with bringing produce to market on a specific schedule. There are several options for providing supplemental light during periods of limited natural light. The most common types are high pressure sodium lights, which provide light that is high in yellow and orange, and metal halide lights, which are more bluish. For a more balanced spectrum, greenhouses use a combination of the two.

A more recent technology for lighting applications is light emitting diodes (LEDs). Panels of LEDs can more easily be adapted to various plant production systems than large bulky high intensity discharge lamp fixtures. LEDs can also be customized to provide specific light spectrums and are expected to become the most energy efficient technology for converting electric energy into light for plants and other applications. LEDs still tend to be less efficient in providing uniform lighting of sufficient intensities over larger areas compared to other types. While the initial cost of LEDs is high, prices are expected to continue to drop. Because of innovations with LEDs, indoor and vertical farming entirely with electrical light sources is now a possibility.

Since electricity tends to be costly in rural Alaska, it may not be worthwhile or feasible to use supplemental lighting throughout the winter. For instance, in the Tok school greenhouse, plants are grown in the winter without supplemental lighting. Although the plants are still growing, they don't grow very fast or large compared to other times of the year. In other Alaska greenhouses, supplemental lighting may only be used to start seedlings and produce transplants for the greenhouse or a garden.

Controls

Automation is helpful in running a greenhouse. It allows the lights to come on, plants to be watered, and vents to open even when staff are at home on the weekend. However, automation requires electricity and more sophisticated systems will need a trained staff member to program operation. Thus, the level of automation for a greenhouse will depend on the purpose and goals of the greenhouse, staffing, type of production systems, and available budget. Control systems can consist of a computer that continuously monitors and records environmental data, senses when something is out of order, and initiates an alarm system. However, simpler systems can also be used to turn lights on and off, open vents, and automatically adjust nutrient levels in hydroponic systems. Advanced as well as more basic control systems require monitoring, ability to override malfunctioning processes, timely response to alarms, backup arrangements, and an ability to understand and make corrections.

Ultimately, it's up to the project team to make the decision on whether or not to install automation, and how much to install. If you do install control systems, take the time to train staff on how to use them properly.

Interior layout

Before you build, think about how your team will use the interior space. Consider utilities, storage areas, horizontal and vertical planting structures, room for workers or students, and areas for handling seedlings and harvesting. Think about who needs to access the greenhouse: schools may need wider aisles and tables than a commercial greenhouse. Similar to many houses, adding an arctic entryway can be recommended to prevent cold air from rushing into your heated space. If you don't have a greenhouse professional guiding your layout design, try drawing different scenarios for your greenhouse footprint, then share them with others to solicit feedback (ideally someone who has experience running a greenhouse).

Utilities: Where will water and electricity come from? How much of these resources will your operation require? Spend some time thinking about where and in how many locations you will need electrical outlets, water supply, hookup for fans (exhaust, mixing, horizontal air flow) and ability to install and connect light fixtures. Also, consider the heat distribution system, and how everything will fit together, get monitored and controlled.

If the project team hasn't yet chosen a growing methodology, this is the time. Hydroponic and aquaponic systems require electricity to run pumps. They also need a steady supply of water. In areas with expensive or unreliable electrical service, it is best to start with a soil-based system.

Plant support structures: If support structures will be used for the plants, they need to be sufficiently strong to hold fully saturated containers. Benches are usually 30-36 inches tall and less than 4 feet wide. Access from both sides is needed for the wider benches. They are often made with slatted wood or wire mesh to allow for drainage and good air circulation around the plants. Some plants do better in vertical configurations, such as in hanging pots or baskets, or on suspended trays. For tall plants, ground or raised beds with or without wood frames, or large containers placed on the floor work well. Vertical high-wire systems are commonly used for growing tomatoes and cucumbers. If you're going to use a trellising system, it will be more effective to plan the system during the design phase of the greenhouse.

Storage and processing space: Storage areas for tools, supplies, containers, growing media, cleaning products, chemicals, fertilizers, and safety equipment are essential for greenhouses. Keeping the storage area labeled and well organized allows for efficient operation. Materials such as fertilizers, chemicals, and pest control products should be in a lockable storage area with the corresponding Safety Data Sheets, which outline the safe handling and required protective equipment for products. Building plans should also include service and processing space for managing, packaging, and storing harvested products. If plants are started as seedlings, you may want to include an area for seeding, germination, and transplanting. In addition, space for breaks, personal belongings, office functions, shower and bathroom facilities are often needed to run the greenhouse efficiently.

In Alaska, shipping is expensive. Consider adding a large storage area to your greenhouse so you can order materials (soil, fertilizer, etc.) in bulk and store the extra.

Plants rest on wire bench in a greenhouse at the University of Alaska Fairbanks. The wire bench allows water to drain from the pots onto the cement floor, where it then flows to a drain.

Resources

This chapter only covered a very basic overview of the many features of greenhouses. To learn more, visit greenhouses in your area and ask their staff what features they like, and which ones they would switch to something different. Also, here is a list of helpful websites and publications:

Cold-Climate Greenhouse Resource: A guidebook for designing and building a cold-climate greenhouse: This handbook is the result of a collaboration between Eagle Bluff Environmental Learning Center, the Center for Sustainable Building Research, the Southeast Regional Sustainable Development Partnership, the University of Minnesota Extension, and the Center for Urban and Regional Affairs at the University of Minnesota. In addition to practical tips on cold climate greenhouse design and components, the appendix contains profiles of cold climate greenhouses in operation.

Economic Analysis of Greenhouse Lighting: This technical article is a good resource for project teams looking to gain an in-depth understanding of how to compare lights for efficiency.

Energy Self-Assessment: This website, from USDA Natural Resources Conservation Service, contains energy conservation tools that can help farmers identify ways to reduce energy costs. The tools help calculate an estimate of the energy usage of different farm equipment.

Greenhouse Engineering: This publication, from the Natural Resource, Agriculture, and Engineering Service in Ithaca, New York, is a comprehensive resource on every topic of building a greenhouse – from initial planning to heating and cooling to pesticide storage.

National Greenhouse Manufacturers Association: This website contains downloads with topics including designs, guidelines for lighting and ventilation systems, and helpful hints for general greenhouse features.

Wisconsin Statewide Wood Energy Team: This team has published several files on heating greenhouses with wood. The resources are comprehensive – from how to first reduce the energy consumption of the greenhouse to where to place greenhouse unit heaters.

University of Alaska Fairbanks Cooperative Extension Service (UAF CES): UAF CES has a number of publications on greenhouses. The publications are aimed at homeowners and gardeners, but contain information on greenhouse design and systems in Alaska.

The Winter Harvest Handbook, by Eliot Coleman: This book focuses on unheated greenhouses, but the chapters on cold and cool greenhouses contain useful information on greenhouse design in cold climates. The book also contains information on crops, soil preparations, and pests. The book is published by Chelsea Green Publishing.

Virtual Grower 3: This free software, available for both PCs and Macs, is a greenhouse energy-modeling program. Developed by USDA Agricultural Research Service, the software allows users to build a greenhouse with a variety of materials, styles, and temperature setpoints. The software predicts heating costs and plant growth for different sites in the United States.

One of the greenhouses in Dry Creek, Alaska.

4

BIOMASS HEATING

OPTIONS AND EXPLANATIONS
OF BIOMASS HEATING

BIOMASS HEATING

BIOMASS OPTIONS AND EXPLANATIONS

PRECEDING PAGE: Cordwood storage in Coffman Cove

The construction of a greenhouse is only half of a biomass-heated greenhouse project. The other main part of the project is of course choosing, installing, and learning to operate a biomass appliance. Alaska contains 126 million acres of forest, approximately one third of the state's area. This forest varies by location from temperate rain forests in Southeast to spruce forests in the Interior. There are many biomass products for heating that come from these forests, ranging from freshly cut logs to processed biobricks. The type of biomass fuel that you will choose for your location will depend on local availability and the your project's needs and resources – the heat load of your building, which biomass heating appliance has been selected, staffing capabilities, and community support. There are three main biomass fuels:

In addition to selecting a biomass fuel, your project team will need to carefully choose a biomass appliance. The biomass appliance should be a proven technology. It should be energy efficient and feature low emissions. Look for other users of an appliance before you make a purchase and visit them if possible. Ask about the operations and maintenance of the appliance and whether they would purchase the same appliance again. If your project will be purchasing insurance, talk to the agent about which biomass appliances can be included in the policy.

Cordwood: Cordwood comes from trees that are cut, bucked into length, split, and dried. Cordwood heating appliances should be carefully selected: look for clean, high efficiency systems from well-known companies and speak with other users of the appliances to learn about maintenance requirements and customer satisfaction. Cordwood boilers that burn efficiently and cleanly tend to be large, heating buildings of a size between 5,000 and 500,000 square feet. Typically, cordwood appliances cost less than appliances that burn chips or pellets. However, the operation of the appliance is more labor-intensive. Logs must be split, stored, and dried. The appliance will need to be fueled and cleaned by hand. Projects with a staff capable of running a cordwood boiler may find the extra job in the community a welcome requirement!

Chips: Wood chips are made from trees that are run through a chipper. Thus, wood chip heating systems have some upfront costs that cordwood systems do not face, including the chipper and a clean storage unit to hold the chips. However, the labor requirements for operating the appliance are lower. Chips can be fed into a boiler automatically via an electrical auger. Chip biomass boilers are suitable for large heating loads, usually more than 10,000 square feet, but smaller systems have recently been introduced in the market.

Pellets: Pellets are a highly processed biomass fuel, and are manufactured from a variety of biomass products such as sawdust, lumber mill scrap, and trees determined unsuitable for lumber. Their uniform, small shape allows pellets to work well in automated feeding systems and smaller size boilers. Pellets are the most expensive biomass option. They are only available from a pellet plant, and require a dry storage location. On the other hand, they are often drier and contain more energy than other biomass fuels. Pellet systems also tend to be highly automated, requiring less labor for operations and maintenance. Pellet systems are available in a large size range, from buildings ranging from 1,000 square feet to those over 100,000 square feet.

Alaska biomass resources

Interest in biomass heating systems has been growing in Alaska and there are many resources to help with a decision about a new system. The United States Forest Service Wood Energy Project has produced two handbooks, on Thermal Wood Energy and Alaska: Where Woody Biomass Can Work that provide a basic overview of biomass systems and case studies of systems currently in operation. Hard copies are also available from the communications group at the USDA Forest Service Pacific Northwest Research Station (503-808-2125). The Wood Energy Financial App is a great place to start to determine if your project will be cost effective. You'll need some basic information before you start: the current heat source and how much fuel it uses, the type and cost of the proposed biomass fuel, and a rough estimate of capital costs. The USDA Natural Resources Conservation Service has an energy self-assessment that can help evaluate the savings in switching to a biomass appliance, performing energy conservation, or using other types of renewable energy. Links to other resources to get started appear below:

The Tanana Chiefs Conference located in Fairbanks has a forestry program which has developed biomass assessments for communities around the state. Their website provides biomass assessments for the Upper Kobuk Region, Interior villages, Fort Yukon, McGrath and Tanana. There are also inventories from Ahtna villages, Nana region and Bristol Bay Native Association.

UAF Cooperative Extension Service

- Hauling and transporting wood safely
- Drying and storing wood
- Wood availability by region
- Wood energy content

Federal resources

- U.S. Bureau of Land Management
- U.S. Forest Service

State resources

- Alaska Dept. of Natural Resources
  - Division of Forestry
  - Firewood from state lands
  - Public Information Center
  - Division of Wood Energy

Native corporations

- Bering Straits
- Cook Inlet Region, Inc. (CIRI)
- Calista Corporation
- Doyon Limited
- Koniag Incorporated
- NANA
- Sealaska
- Aleut Corporation
- Bristol Bay Native Corporation
- Chugach Alaska Corporation
- Afognak Native Corporation
- Ahtna
- Arctic Slope Regional Corporation

Local market assessment

A biomass system can be a boon to the local economy as money that was being paid to buy fuel from far places can be transferred to paying local people to supply a local resource. When weighing benefits and drawbacks of a biomass system keep in mind any local jobs that might be created. In addition to collecting biomass, biomass appliances require people to operate and maintain the systems – all jobs that keep money circulating in the local economy.

Biomass supply: Is biomass available locally and will it be available in the future? Who owns the land where the biomass comes from? Is it in a location that is accessible for biomass harvest? What biomass fuels are locally available? Has a biomass assessment been completed in your area? Ask the Alaska Division of Forestry, the Alaska Energy Authority, local governments, and Native Corporations if they have done a biomass assessment for your region.

Transportation: How will the biomass resource be transported to your location? Who will transport it and how much will the transportation cost? At your location, where will you receive it? Can a large truck drive up to your storage shed?

Storage: Where will the biomass be stored? All types of biomass need to be dry to burn efficiently. Pellets will come dry from the manufacturer; green cordwood and chips will need to be dried out – how do you plan to dry it? How will you store the biomass so that it stays dry? Many projects use covered sheds to protect their biomass fuel from rain and snow.

Cost-effectiveness: Is the cost of biomass competitive with heating oil or natural gas? Local energy prices will determine if a biomass project is cost-effective in the long run. It's important to carefully review the cost and savings of using biomass fuels. The Wood Energy Financial App is helpful in analyzing the savings from biomass use.

Community capacity: What is the local capacity for installation, operation, and maintenance of a biomass appliance? Are there other biomass heating systems in the area? It's important to talk with people in the community about the advantages and disadvantages of a potential project, and listen to their feedback. Projects with community support are much more likely to succeed in the long-term.

Moisture content refers to the amount of water that is contained in biomass. Freshly felled green trees can have a moisture content of 50%. For heating appliances, it is important that your biomass fuel have a moisture content of less than 20%, and the lower the better. Biomass with high moisture content has major drawbacks compared to dry biomass:

1. Water weight displaces the available wood fiber in each ton. This lowers the amount of energy available for heating a building. Therefore, one ton wet biomass will provide less heat to a building than one ton of dry biomass.

2. Wet biomass burns at a lower temperature, causing more emissions and building creosote on the stack.

There are two scales to determine moisture content: wet basis and dry basis. Typically, the biomass community uses wet basis moisture content, calculated by:

Wet Basis Moisture Content = $(\text{Weight}_{wet} - \text{Weight}_{dry}) / \text{Weight}_{wet}$

You can measure the moisture content of biomass yourself. For cordwood, simple inexpensive wood moisture meters are available. To use a meter, split the wood piece you want to measure and drive the pins into the freshly split side of the wood, parallel to the grain. To measure the moisture content of wood chips, you will need an accurate scale. After measuring the weight of a handful of un-dried chips, place them in an oven to dry, usually for 215°F for four hours. Then, weigh again. Put them back in the oven for 4 hours, and weigh them again. Continue this until there is no weight change and then use the formula above to calculate the moisture content. Chips can also be dried using a microwave, drying chips on medium power for about two minutes at at time.

LEFT: A firebreak under construction near Tok, Alaska.

Choosing the type and size of the heating system

Once the project team has chosen to pursue biomass heating, it's time to narrow down the type and size of heating appliance that the building will need. No matter what the decision on the type of biomass fuel to use and the size of the appliance, make sure to carefully select the appliance. Clean technologies feature high efficiencies and low emissions. The U.S. Environmental Protection Agency and similar agencies in Europe certify appliances that meet certain efficiency standards. Ask manufacturers about certifications and if you can speak with current users of the appliance to ask about their experience.

Fuel type: What fuels are available locally? Also, what is the size of the space you are trying to heat? Pellet systems can be the smallest in size, delivering up to approximately 300,000 BTU/hr. Cordwood systems are mid-sized, delivering around 200,000 to 750,000 BTU/hr. Wood chip systems are usually the largest, delivering 1 MMBTU/hr or more.

Sizing: Typical heating systems are sized to meet the heating demand on the coldest day of the year. Biomass boilers cannot be sized this way because they cannot modulate their output as well as fossil fuel appliances. A biomass boiler operating at the low end of its operating range burns less efficiently and can have higher emissions. It is best to size the biomass boiler to deliver approximately 80% of the heat need on the coldest day and use an oil or natural gas boiler as a backup. It's best to work with an experienced biomass engineer to properly size a biomass appliance.

Backup heat: Biomass systems should contain backup appliances. These backup appliances will run on the coldest days to meet peak heat load requirements for the building, and during times when the biomass appliance is offline for maintenance. In areas with fluctuating power it is best to have the electrical components of your biomass boiler on a battery/surge protection system as power fluctuations can cause serious harm to electrical components.

Biomass appliance for school and greenhouse: The economics of biomass systems improve when more buildings and heat loads are included in the system. Typical biomass boilers deliver more heat than one small greenhouse will need. If you are only heating the greenhouse, and not another building, make sure that the biomass boiler is properly sized so it can operate efficiently. It may be a better idea to explore other smaller biomass appliances, such as a pellet stove or masonry stove. Of course, with any appliance, you will need to know who can install the appliance and if the fuel type is available locally. A certified installer should install a masonry stove and pellets and pellet stoves may not be available in rural locations. If the biomass system is already in-place heating another building, the presence of a greenhouse can improve the overall efficiency of the system by adding load during low-load periods, such as overnight. However, it can also result in a shortfall of heat if the boiler is not capable of meeting the heat load for both buildings. Again, it's best to consult an experienced biomass engineer to ensure the appliance is properly sized for the project.

Heating appliances in the United States are typically rated by their power, or the amount of heat the produce in one hour. The power is usually given in units of MMBTU/hr. To get an idea of how much heat a biomass appliance produces, you can think of 1 BTU as approximately the amount of heat produced when 1 match burns completely. And MMBTU is 1,000,000 BTUs. So a heating appliance that is rated at 1 MMBTU/hr has the same power as if you burned 1,000,000 matches in a hour.

Thermal storage: Reputable cordwood and chip style boilers come with large thermal storage tanks. The boiler heats the water inside the storage tanks each time it is fired. All the heat from firing the boiler is then stored in the water until there is a call for heat from the conditioned space. Thermal storage is necessary because biomass boilers cannot modulate the amount of heat they deliver; the storage allows them to burn all the biomass at once at a high temperature, which means they burn cleaner and more efficiently. Thermal storage should be added to boiler systems that do not already come with it. It is a red flag if a vendor tries to sell a biomass system without thermal storage.

Siting a system: A biomass boiler produces smoke and ash, so it should be sited away from doors, windows, and air intakes of buildings. Ideally, the appliance will have its own dedicated space. Additionally, the biomass appliances can be rather large, especially if it has a water thermal storage system. If possible, it should be located near the buildings that are receiving heat. Shorter distances between the biomass appliance and the buildings means less plumbing and less heat lost in transport.

Student boiler operators at the Prince of Wales School.

Acquiring and delivering biomass fuel

Transporting fuel from the source to the boiler is the most difficult part of every operations plan. The project team should have a plan in place before construction begins. If biomass is coming from a sawmill or similar industrial site, then the project team will need to plan for minimal handling and moving the fuel to your location. Without a mill to provide waste materials, your team will need to figure out how to get wood from the forest to the boiler. There are a few options:

- Find a supplier that can acquire and deliver biomass already processed. This is the best option for ease of operations, liability, and reliability. If the biomass can be delivered dry, that's even better.

- Find a supplier to acquire and deliver in log form for your team to process into cordwood or chips and dry. In this case, your organization will need to handle training employees; coordinating delivery, processing, and burning; and liability issues. For example, cordwood needs to be delivered, cut and split, and dried before it can be burned. Employees working with chain saws and moving logs should have proper training and equipment.

- Acquire and deliver your own biomass. This is the most labor-intensive option. In addition to handling transportation and processing, your team will need to consider harvest permits and reforestation. The operations plan will need to ensure all employees are properly trained and equipped, and your team should consult your insurance company to ensure your plan covers all necessary activities.

- If you live on a major river, like the Yukon, you may be able to collect enough biomass from driftwood to sustain a biomass boiler. You'll need to do an assessment of driftwood before deciding on this option.

Wood hauling rig and chipper in Galena.

Superior Pellets' chipper in action.

Fuel storage

Biomass requires a great deal of storage space. It also needs to be stored in such a way that the biomass is either drying out or kept as dry as possible.

Open-sided sheds with a roof are good for cordwood, especially if it is stacked. Getting cordwood to air dry to 20% moisture content takes time. Drying time varies depending on the local climate and when the wood is harvested. Split and cross-stacked cordwood in a shed with open sides and a roof can dry in Fairbanks within 6 weeks in the summer if conditions are optimal. Fall-harvested wood will take up to a year to dry even if it is split and stored in a covered location. In Southeast Alaska, split wood can take a year or more to dry. It is best to plan a year in advance, which means next year's wood is stored and drying in the current year.

Chips need to be in a covered shed with some air movement as well. However, it is harder to dry chips once they are chipped. It is best to let wood dry to 20% moisture before chipping it. For instance, operators of wood chip systems in Tok and Galena stockpile wood in the forest to dry for a year before transporting and chipping it. Stacks should be 3 feet high or less so can dry without any of the wood rotting. The USDA Forest Service Pacific Northwest Research Station is currently conducting a study in Haines to determine optimal passive drying and chipping strategies.

Pellets also should be stored in a dry location so they don't absorb moisture. They should be stored off the ground (they can absorb moisture from wet soil). The storage area should have ventilation, especially if it is accessible by staff. Ideally, pellets will be stored in a hopper or silo near the pellet-burning appliance. No matter where the storage area is, be sure it is accessible for the delivery trucks, which often use augers to transfer pellets into the storage container.

At Thorne Bay School on Prince of Wales Island, cordwood is delivered on pallets, each holding a half-cord of wood.

The chip storage shed at Logging and Milling Associates located at the Dry Creek Community.

Tok School's shed can hold about 1/7 the chips they need for the year. They are working on getting a timed delivery so their chips do not sit out in the weather.

Pellet storage at Superior Pellets in North Pole.

The interior of the biomass-heated greenhouse at Tok School features two heat distribution systems. The forced air unit heaters hanging from the ceiling heat the greenhouse atmosphere, and the raised beds in the rear of the greenhouse feature in-bed heaters. Distribution lines run along the ceiling and down to the beds in the back right of this photo. The beds in the foreground do not have bed heating. The different soil temperatures between the heated and non-heated beds allow the greenhouse manager to place plants in a bed with a soil temperature best for the particular crop.

Distribution system

A biomass boiler produces hot water, which it then distributes to a building via a distribution system. The hot water is pumped through pipes to heat exchangers in a building. The type of biomass boiler will have an impact on the type of distribution system. For instance, in-bed distribution systems can utilize lower temperature water than unit heaters. Think about the temperature of water that the boiler will produce when choosing a distribution system.

Distribution is coordinated by a control system that takes into account the design and layout of the heating system and building. Pumps need to be activated to appropriately move hot water when the temperature drops to the heating set point in order to maintain an optimal environment for plant growth. A good control system should be easy to understand and operate without requiring significant technical training or background.

Various methods can be used to deliver heat:

Forced air / Unit heaters: In this system, unit heaters are usually suspended from the ceiling. A fan in the unit heater blows air over pipes carrying heated water from the boiler and into the room. In smaller greenhouses, the fan is able to uniformly distribute heat while in larger areas a polyethylene convection tube may be needed. The fan moves warm air into the tube and it exits through side holes along the length of the polyethylene tube.

Baseboard: Baseboard or fin pipe distribution systems are typically installed along the lower section of outside walls. The hot water is pumped through pipes in the baseboard. The thin metal plans or fins inside the baseboard efficiently distribute heat from the pipe to the air. As the air around the pipes warms, it rises above the baseboards into the room via convection.

Bottom or in-bed: A distribution system that uses heating pipes placed underneath or in ground beds is intended to warm the soil and roots. This system is usually combined with forced air or another system to heat the air surrounding plants above ground. Some plants respond to warmer soil with improved growth, so the air temperature in the greenhouse can remain lower than without bottom heat. Since heat is provided directly to the soil, it can be an efficient method of heating crops, but make sure soil is not too hot for your crop.

Thermal mass: Thermal mass refers to the ability of an object to hold heat and then slowly release that energy to a colder environment. Often one or several tanks of water are used as the thermal mass. The water can be heated during the day by solar energy or anytime by the biomass appliance. The heat is then released when it gets colder during the night in the greenhouse. The release of energy from the thermal mass is unregulated and occurs when there is a temperature difference between the thermal mass and the surrounding air. If designed well, it could serve as a thermal battery to hold the greenhouse over and avoid having to load the boiler during the night.

The greenhouses in the Southeast Island School District utilize thermal mass in the form of the water circulating in the greenhouse aquaponic systems. All of the water in the system passes through the heat exchangers on the cordwood boilers twice a day, where it is heated to 75°F to 80°F. The greenhouse then has thermal mass in the form of thousands of gallons of water in the insulated aquaponic system.

Operation and maintenance

From biomass collection to the delivery of the heat, operating a biomass heating system will require many pieces of equipment. Written operation and maintenance plans are imperative to the smooth running of the complete system. Plans need to include basic maintenance information as well as who is responsible for the various steps and aspects of the system. In addition, the required training for the operators needs to be clearly stated and outlined. The plans should be easy to find and available to everybody with a role in the heat-delivery system.

Boilers require daily maintenance, from filling the firebox to cleaning the ash. For smaller systems, existing staff may simply perform the added maintenance tasks. However, for larger, more complex systems, you may need to hire a biomass heating specialist. This can be an important employment opportunity in the community and should be accounted for in the cost analysis. If the biomass system is large enough to supply heat for several buildings, the cost of this position can be shared among each building's maintenance budget.

A boiler with automatic feeding will require more maintenance than a manually fed cordwood boiler. Mechanical feeding systems tend to have many moving parts and servicing requirements. If you are collecting and processing wood chips, the harvesting equipment may be the most high-maintenance part of the entire system. The manufacturer of harvesting and boiler equipment should provide checklists for daily, weekly, monthly, and yearly maintenance requirements. On the other hand, cordwood boilers require an operater to stock the boiler, which might be up to 3 to 4 times per day in cold weather. Other maintenance tasks include removing ash, and daily and weekly inspections.

Every biomass heating installation is unique to the specific situation and location. A solution that works in one community may not be suitable in another. The best source of information for various biomass heating options are the people operating them.

TOP: Maintenance of the wood chip boiler at Tok School. Ash is removed daily from the firing box. This boiler provides heat for the school, greenhouse, and athletics building. It also is coupled with a generator to offset the school's electrical use. The system requires a full-time operator.

LEFT: Automatic feeder systems have many components and require regular preventative maintenance. Poor quality chips will cause more clogs in the system. In Alaska, frozen chips also cause plugged feed conveyors. The feeder system for the boiler at Tok School is equipped with an alarm to automatically call an operator when it is clogged.

Biomass - Getting started checklist

- ✓ Do you have a community champion to lead the project?
- ✓ Do you have a vision statement?
- ✓ Does your community support the project?
- ✓ What is your biomass resource and where will it come from?
- ✓ Who will operate the system?
- ✓ What buildings are you heating?
- ✓ What is your heat delivery system?
- ✓ Is biomass cost effective?
- ✓ Have you talked to people who have biomass heating systems? They are your best source of information on how systems really work.

"We also look at capacity, it's not just 'Let's heat schools with wood or put on solar panels.' You need to look at the capacity of a community and not just the school or city hall to operate the system but also the capacity of the community to support the system. If there is no desire to heat with wood, then it's better to stick with what you have or else the whole system will fail and you will have invested a whole bunch of money."

- Karen Petersen, University of Alaska Fairbanks Cooperative Extension Service

Brad Cox with the Dry Creek Community biomass boiler.

5

GROWING

CROPS AND PRODUCTION SYSTEMS

PRECEDING PAGE: Lettuce grows in an aquaponics system in the greenhouse at Thorne Bay School.

Is your greenhouse built already? Or, perhaps planning is in progress for the building and your project team is looking ahead to the next step. Planting, growing, harvesting, selling, eating, learning – this is why many biomass-heated greenhouse projects exist. At the center of a greenhouse project is the plants, and this chapter aims to give readers vocabulary and basic knowledge to get started with gardening.

Growing methodology

There are several methods of growing plants, such as in field soil, in a soil-based medium in a container, or in hydroponics with a water-based nutrient solution. If production of fish is included in a hydroponic system, it is called aquaponics. These methods can also overlap. They all have advantages and disadvantages, so it's a great idea for the project team to discuss which one will fit their situation the best. This discussion is best held before greenhouse construction, so that the building design can be optimized for the growing system.

Three questions to consider as the project team discusses the different growing options are below. And remember, with any growing system, as the team gains experience, you can adjust it to what fits the project the best.

How much experience does your staff have with agriculture? Especially for greenhouse staff, teachers, and students that are just starting out, SIMPLE IS BETTER. The fewer parts and procedures a system has to figure out in the beginning, the easier it will be to learn. Then, you can always expand as staff gains experience.

What are your priorities? A large variety of crops grow well in field soil, so education-oriented projects that are providing space for experiments or hosting a plant collection to show students might want to use a soil-based system. Similarly, if your aim is to give students skills to start a home garden, soil-based systems might be a good choice since families can replicate them at home. On the other hand, hydroponic and aquaponic systems lend themselves to large-scale production. One compromise would be to run a hydroponic system inside a greenhouse, and have a few raised beds outside.

What do you want to grow? Different plants grow best in different systems. Hydroponics works well for leafy vegetables like lettuce. Soil is best for root vegetables like potatoes and carrots, and potted soil growing systems are good for growing flowers or houseplants for sale.

Soil-based systems

For people who don't work in agriculture, plants grown in soil are likely what comes to mind when they hear the word greenhouse, garden, or farm. In a greenhouse, plants can grow directly in the ground–such as when a hoop house is erected over a piece of land. Or, plants can grow in raised beds of soil. Finally, plants might grow in pots.

Soil has many advantages as a growing medium as it accommodates many plant types. Also, if you are training students or volunteers to garden at home, a soil growing system is most easily

Two different growing systems exist side-by-side in the educational greenhouse at the University of Alaska Fairbanks. The box in the foreground is a simple hydroponics system: The container is filled with water and nutrients and the plants are supported by a foam raft. In the background are pots of soil that students use to grow plants as part of a course on horticulture.

replicated. Farming in soil in the ground, or in raised beds, also allows plants access to moisture, earthworms, and more depth for the roots. Finally, soil acts as a buffer for water and nutrients. On one hand, this means that farmers don't have immediate control over those variables. On the other, farmers (especially beginners) have some leeway in watering and fertilizing to find the correct balance for a crop.

For any soil system, there will be initial work necessary to ensure the soil has suitable structure and nutrients. Between each harvest, staff will work the soil and add nutrients. During initial set-up, consider your future gardeners and the length of their arm; rows of vegetables in the ground or raised beds should be narrow enough that arms can reach to the middle without stepping on plants. Also, plan to regularly test the soil. In Alaska, the University of Alaska Fairbanks Cooperative Extension Service can direct farmers where to send soil for testing. A soil test will tell the farmer what nutrients are in the soil, and what nutrients need to be supplemented.

Soil needs good structure to provide air to plants and to promote biological activity. Materials that help add pores to soil include sand, perlite, peat moss, and coconut coir. It promotes drainage while still holding some moisture. Staff will also need to work nutrients into soil via compost or commercial fertilizer. Crops should also be rotated to prevent pathogen build-up in the soil.

Many greenhouses also pasturize soil annually. When done correctly, pasturization removes pests and plant diseases that may be growing in the soil, while conserving the soil structure and the beneficial bugs. In Alaska, many commercial greenhouses are allowed to freeze each winter to accomplish this. Our cold outside temperature does the work for us–although staff should be careful if there are pipes or equipment in the greenhouse that shouldn't be allowed to freeze. Otherwise, staff can pasturize soil using heat. Soil might be placed in an oven, or sprayed with hot water. Water temperatures for sterilization typically range from 140 F to 160 F, so the good creatures can survive.

Hydroponics

In a hydroponics system plants are supported in a container that allows their roots to access water that contains nutrients. Some systems simply consist of plants floating on a container of standing water; other systems feature pumps that keep water running through pipes around roots.

While roots will not be in soil in a hydroponics system, they are sometimes supported by a medium such as rock wool, perlite, or gravel. Greenhouse staff add nutrients to the water for the plants to access.

With any hydroponics system, expect to continuously monitor the system. The water level needs to be high enough to keep roots moist, an adequate amount of nutrients must be in the water, and pumps need to run in systems with circulating water. Staff also have to monitor the system to ensure it stays free of pathogens such as listeria and salmonella.

Hydroponics systems are good for growing leafy vegetables like lettuce, kale, and herbs. They offer fast feedback to greenhouse staff, but on the other hand, require constant monitoring.

Lettuce grows directly in the ground inside a high tunnel in Kasilof, Alaska. Photo courtesy Alaskan Homegrown.

Megan Fitzpatrick, a teacher for the Southeast Island School District, converted the hydroponics growing system at her school into an aquaponics system after learning about the concept of aquaponics at a conference. In Alaska, aquaponic systems must use ornamental fish, like these goldfish in a tank at Thorne Bay School.

> "People will share with you what has worked for them, but this may not work for you. So get advice, try it, and then adjust it to your own greenhouse."
> - Meriam Karlsson, Professor, School of Natural Resource Management at the University of Alaska Fairbanks

Aquaponics

Aquaponic systems are growing systems that link hydroponics with fish. In an aquaponics system, fish and plants exist in a symbiotic relationship. Fish provide nutrients like ammonia and carbon dioxide for plants, and in return the fish use the nitrate and oxygen from the plants.

Like hydroponic systems, aquaponic systems range in complexity. On the simple end, plants might be growing on floating "rafts" in a fish pond or aquarium. Or, systems might use pipes, pumps, and filters to circulate water between fish and plants. The systems may take a few weeks to become productive as it first must build up nutrients in the water to provide to the plants.

Also, staff will need to continuously monitor aquaponic systems – testing water volume, nutrients in water, and ensure any mechanical components such as pumps are working properly so that water is circulating. The systems are not so simple that the fish produce the perfect amount of nutrients for the plants, and vise versa. Instead, staff will need to monitor the water for the plants and for the fish and be ready to add or filter additional nutrients as needed. Aquaponic systems are not necessarily easy to start with. However, as staff gain experience with a hydroponic system, aquaponics is one way to expand a growing system while decreasing dependence on outside fertilizers.

In Alaska, aquaponic systems are certified by Alaska Department of Fish and Game. It is ILLEGAL in Alaska to grow fish in aquaponic systems for human consumption, so systems in Alaska need to use ornamental species like gold fish. Current Alaskan regulations also specify that the fish wastes and wastewater cannot be released into the waters of the state.

What are you going to grow?

What you grow in the greenhouse and what system you decide to use will go hand in hand. When projects are started, whether or not staff has agricultural experience, it's best to start with fewer species of plants, and allow the project room to expand to more variety later. Starting with a single type of vegetable or flower gives staff the opportunity to learn the routine of the greenhouse and how the various mechanical and control systems work. Also, staff will learn how that particular type of plant grows in your greenhouse – how much light and heat affects the harvest date and growth rate.

Finally, what does your staff want to grow? Asking for input from students, volunteers, and workers keeps interest levels high and gives them ownership of the project. Plus, they will gain experience and learn what plant species may work best.

Growing methodology: As discussed in the previous section, various growing systems can be used. Some cultivation systems are better suited for growing certain vegetables. Soil-based systems are versatile and can accommodate most crops. Leafy greens such as lettuce, spinach and herbs grow well in hydroponic systems.

"What I have now is like a system: a greenhouse with a controlled environment, a high tunnel which is a protected environment, and field crops. I make my plant selection for each based on which environment of the three will work best. Stuff that needs tender care...tomatoes, cucumbers...goes to the greenhouse. Stuff that needs help in the shoulder seasons...such as squash.... goes in the high tunnel. Stuff that is hearty...kale, leaks, collards, broccoli... goes in the fields."
– John Engle, Owner, Corbin Creek Farms
Photo courtesy Corbin Creek Farms.

Growing season: Will the greenhouse operate through the winter, or just to extend the summer season? Crops are adapted to different temperatures and climates. What temperature will be maintained in the greenhouse? Choose crops that will work in the greenhouse environment and the soil temperature you are able to provide. In the winter, the greenhouse may run at a colder temperature to support crops like lettuce, spinach, chard, kale, and radishes. These crops also require less light and will have better taste at lower growing temperatures. In the summer, choose crops like tomatoes, cucumbers and peppers.

Quantity and plant output: What are the goals of your project? If the project is aiming for financial stability through vegetable sales, then choosing a crop with a high output is a good place to start. Many crops, such as spinach, produce multiple harvests from one seeding. This consideration will not be as important for greenhouses with educational priorities.

Plant needs: Plants need heat, light, water, nutrients, and carbon dioxide. The biomass heating system should take care of the plants' heating needs. Plants typically grow faster and produce higher yields under high light conditions. If there isn't enough natural light as during the winter, supplemental light is needed. Nutrients can be added to irrigation water to meet both needs at once. Water and nutrients are often provided to plants in automated systems, though the systems still require continuous upkeep, so consider the amount of labor required to grow a particular crop. Usually you don't have to worry about carbon dioxide, since plants can extract it from the surrounding air.

Market: Where is the produce from the greenhouse going? Is it being sold to a restaurant or cafeteria, or simply given to volunteers and students? Talk to the people buying and eating the vegetables about their needs. Project teams may want to begin with a market survey to help with their decision. For projects that are up and running, consider surveying the customers to allow them to suggest and choose new crops.

Education: Projects that prioritize education need to consider how the chosen plants will fit into the curriculum and the educational programs. Students learning in the greenhouse will appreciate quick feedback from fast growing plants. Even better, students can taste "grow-and-eat" crops like lettuce, immediately after they are harvested! Another school-specific consideration is staffing over the summer months. Possibly students could start crops in May and harvest when they come back in the fall. This suggestion is dependent on at least one staff member managing the greenhouse over the summer.

"I have degrees in horticulture and business management. But most importantly, I have lots of experience."

- Mike Mosesian, Owner, Bell's Nursery

Getting started

The most important item at the beginning is enthusiasm and an eagerness to learn. Of course, supplies, tools, and equipment are needed to start growing crops in the greenhouse. The lists below provide a rough idea of what needs to be acquired through purchase or donation. Keep in mind that the lists are only suggestions and will need to be customized and adjusted to various locations, plant types, and production systems.

The largest expense is likely to be setting up the chosen growing system. Fortunately once purchased, cost of supplies and replacement parts for maintenance and repairs are typically much more limited. Think through the tasks that can be expected in the greenhouse and prioritize high-quality tools. Look for tools that will make the jobs easier and safer to complete. Keep in mind that various students, staff members, and volunteers will use tools and equipment. The level of experience and skills may vary and having sets of tools and gear in various sizes and types may be needed. Seek information and advice from farmers, greenhouse managers, and gardeners on models and brands.

Many crops will be started from seeds. There are various methods of germinating and producing transplants depending on the crop and particular growing system. After a decision has been made as to what crop to grow, suitable varieties need to be ordered from a seed company. The seeds are often sown in flats with individual cells (plug flats) or, for hydroponic systems, in rockwool cubes. A special area or room with optimum temperature and light conditions for germination may be used. As the seedlings grow and reach a suitable age or size, they are transplanted into the containers or for hydroponic placed directly into the system. The amount of seed and growing media is based on the number of plants needed for each time the production area is planted.

Growing systems with soil-based media often use different-sized containers to grow plants. The containers are frequently placed on benches or some other type of support but can also be kept on the floor. Ground or raised beds offer an alternative to individual containers for growing the plants and may require lumber for construction. The amount of growing substrate will depend on the size of the containers or the type of beds used. Hydroponic systems are often specialized to use specific containers, channels, growing substrates and fertilizer techniques. In a hydroponic production approach, you also need pumps, filters, aeration and water testing equipment.

Office supplies and labels for identifying plants are needed for good organization and record keeping. Depending on the crop, specific supplies and tools are needed to harvest and process, such as knives, scissors, harvest containers, scales and materials for packaging and marketing. If you have outdoor gardens, you will also need shovels, rakes, hoes, trowels, pruners and irrigation supplies.

Growing system: soil
Potted plants: pots and benches
Raised beds: lumber to build the raised beds
Soil (calculate the volume of soil that is needed by adding the volume of your pots and beds)
Stakes
Fertilizer

Growing system: hydroponics
Containers for water (standing water or piping system)
Testing kit(s) for water
Plant containers
Medium for roots (water, rock wool, perlite)
Stakes
Pump(s)
Fertilizer

Growing system: aquaponics
In addition to the hydroponics supplies,
Fish container
Fish
Fish food
Fish net
Fertilizer

Growing system: seed starters
Pots of various sizes (depends on what plants will be grown)
Soil (calculate the volume of soil that is needed by adding the volume of your pots or beds)
Seeds

Gardening tools
Shovel
Rake
Hoe
Compost bin
Watering can
Hose
Trowel
String
Pruning shears
Tool cleaning brush
Sprayer
Garbage can
pH meter

Monitoring
Thermometers for compost and soil
Clipboards
Pencils
Notebooks

Harvest
Harvesting bins
Knife/Scissors

Processing
Scale
Salad spinner
Bags
Labels

"It's a lot of work and a lot of worry. You are dependent on the equipment working in the greenhouse. The heater, the watering device, the timers, the valves. It's a risk. But in May…when [the tomatoes] start getting ripe…when stores and customers are asking for them…when they arrive on the market. When they go from green to cream to red. That's exciting."

–Mike Mosesian,
Owner, Bell's Nursery

Photo courtesy Bell's Nursery.

Plant & greenhouse care

Taking care of plants in a greenhouse can be expected to be different compared to field production or outdoor gardening. The greenhouse plants will get some light and heat from the sun but need to be provided with everything else. In addition, the faster growth and development require more constant care and attention than usually expected for a similar field grown crop.

A common task in a greenhouse is watering. Even if the irrigation is automated, the systems need to be checked and cleaned regularly. Watering by hand provides a good opportunity to observe and inspect the plants for nutritional, pest or other problems. The development and growth can also be closely monitored while watering each plant, for more precise timing of cultural procedures such as transplanting, trellising or harvesting.

Nutrients are often mixed with the water and provided as the plants are irrigated. Since this is often the only source of fertilizer the plants receive, it is important to have a schedule that outlines the amounts and type of fertilizers to use. The nutrient solutions need to be mixed correctly and in sufficient amounts to ensure all plants are fertilized. This applies to hydroponic systems as well as for plants grown in a soil-based media.

The environment needs continuous monitoring to ensure temperatures and humidity are kept at the desired levels for the particular plants grown. As seasons and outdoor conditions are changing, the heating, ventilation and cooling systems are likely to require adjustments to work well and remain efficient. Low velocity internal air circulation or horizontal airflow is helpful to maintain a more uniform temperature environment. Air circulation also keeps the plants and foliage drier to discourage fungus growth and plant diseases. A slight breeze in corners and among closely spaced plants is especially important.

Keep the growing-, working- and greenhouse-areas as clean as possible. Not only will the greenhouse look more professional, removing decaying plant material reduces the risk for pests and diseases. At harvest, prioritize good hygiene with frequent hand washing and keeping hair tied back. If containers and flats are reused from one crop to the next, it is often easiest to clean them immediate after harvest. Allow the washed items to dry completely before moving them to storage. This process is more likely to result in a clean start for the next crop.

A greenhouse with many users will benefit from good organization. Clear guidelines with supplies and tools in specific labeled locations can be expected to improve collaboration among user groups. This also makes it easier to maintain inventory and re-order materials in a timely manner. Since shipping can be significant to remote locations, being able to use options with less speedy delivery and lower freight rates can significantly reduce the overall cost.

Planning and scheduling the use of the greenhouse space throughout the year can be a significant task. There may be several projects intended for educational purposes as well as a simultaneous desire to grow vegetables for the community. Crops have different rates of growth and it may be necessary to select fast growing plants to fit with educational schedules, even though slower growing plants would better illustrate a particular concept. In a greenhouse for production, the success of the operation or business is often linked to the efficient use of space for yields and productivity.

Taking the time to keep a greenhouse journal with notes on crops grown, tasks completed, maintenance issues, problems encountered and any other significant observation or experience, will be a valuable resource for the future. These records can be used to plan the next season or the next several years. Issues with a certain type of tool or brand may suggest looking for an alternative. Labor requirements and the success of various crops are other areas that may be gleaned from these observations. If there is a change in staff, the greenhouse journal can be a significant resource for lessons learned along with methods that worked well.

So what does a typical day look like for someone working in a greenhouse? Bonnie Emery is the greenhouse manager for the greenhouse at Tok School, that produces fresh vegetables for the seven schools in the Alaska Gateway School District. Bonnie works 20 hours per week, which she typically does as 4 hours per day for Monday through Friday. Her typical "day" actually begins the prior shift, which she tries to end by considering what needs to be done first when she comes in next.

Each day:
- Arrive and observe.
- Might start with what she planned the day before, or find that she needs to start with something else.
- Make a plan for the day, and get everything ready that she will need. Get the tools out.
- Four days a week she is joined by 4 students in a gardening class.
- She begins maintenance tasks on the schedule: weeding, harvesting, processing plants; building maintenance tasks such as washing the greenhouse sides to improve light transmission.
- End the day thinking about what she needs to do the next day.

Examples of daily tasks:

- Check and water plants
- Check that mechanical systems are working as expected (the temperature feels right, the lights are on, water pumps are working)
- Mix fertilizer
- Scout for pests
- Plant seeds for the next crop
- Label beds with type of seed was planted
- Prepare media and containers
- Transplant seedlings
- Prune and trellis plants
- Weed
- Harvest
- Prepare harvest for delivery
- Clean floors, workstations, and tools
- Shred and compost discarded plant materials
- Turn compost pile

Examples of data to record:

- Greenhouse temperature and humidity
- Temperature and humidity of each zone, if there is more than one
- Light levels and daily hours
- Outside weather (sunny, cloudy, rain)
- Crop cultivars, selections seeded and grown
- Seed sources
- Seeding dates
- Germination dates and percent germination
- Staff who planted or transplanted a crop
- Fertilizer schedule and application rates
- Plant observations (rate of growth, flowering)
- Observed pests and diseases
- Pest control methods and efficiency
- Harvest dates
- Delivery dates
- Dates of building and appliance maintenance tasks

One section of the greenhouse at the University of Alaska Fairbanks is dedicated to a plant collection that features plants from other climates. Students from horticulture classes visit the greenhouse to see the live plants they are learning about. These potted plants are watered by hand by greenhouse staff, which gives the staff members a chance to check their overall health.

Irrigation

Water is a main requirement for plants. In greenhouses, staff might water by hand or use an automatic system to water plants. The quality of the water is important and if it comes from a non-potable source, it should regularly be tested. For instance water from a rain barrel should be tested to ensure it is free of contaminants that may have come from roofing materials or bird droppings. Especially when used to water leafy vegetables that are eaten with minimal processing.

Depending on where the water comes from, a tempering tank may be needed in Alaska greenhouses to warm the water. Cold water can slow growth by chilling the plant and the growing media. A large water tank can also act as a heat reserve to buffer the greenhouse against rapid temperature changes.

Hand watering

Hand watering works well for plants that may require different amounts of water such as variable sized plants or containers. For plants that are frequently moved or grown for a limited time in one area, hand watering is also practical. Going through the greenhouse and spot water the plants that have dried out while passing by those that are still wet reduces the risk for overwatering that can be detrimental to plants.

Watering by hand gives the staff an opportunity to observe the plants for any potential issues such as nutritional, pest or disease problems. It also offers an opportunity to observe the plant development to better plan for crop procedures such as transplanting, pruning and harvest. For new staff, hand watering provides an opportunity to understand how to water plants in various types of production systems. The staff member can pick up the plant and container before and after watering to learn how much water is needed. The water draining through the growing medium and out the bottom provides an idea of how quickly water is moving and that the container is watered all the way through. The disadvantage to hand watering is the amount of labor and time. The plants usually need to be checked daily and somebody will need to come in on weekends and holidays to water.

Hand watering systems should feature quality equipment such as quick-connect and turn-off valves, water wands, and hoses. It's important to plan for storage too, such as where the hose and water wand will hang.

Automatic systems

Automatic watering systems use pumps to circulate and supply water to a drip system, water line, spray nozzle or mister. Although these systems can be programmed to run on timers, they still need to be regularly checked, serviced and maintained. Pumps can malfunction, hoses may break, or drip lines get clogged. Pipes and waterlines should occasionally be flushed and cleaned. However, the system is expected to run automatically with staff not having to come in on weekends or holidays.

Drip systems supply water directly to the soil surface close to the roots of the plant. Since the water is going directly to the growing containers, the floor remains dry to reduce the risk of floors being wet and slippery. Capillary mats are a sub-irrigation system where containers of plants are placed on an absorptive mat. These systems are efficient, but algae and fungus gnats can infest the continuously moist mats and cause sanitary issues. Mist nozzles are used to put water droplets into the air to increase the relative humidity. Many plants grow best at a relative humidity of 60 to 80 percent. Mist systems are sometimes also used as part of the greenhouse cooling system.

The greenhouse at Tok School utilizes an automatic watering system. Timers control water flow to drip hoses in the raised beds. The automated system allows the greenhouse manager to take weekends off, and allows her to customize water delivery for each particular crop.

Nutrients are added automatically to the hydroponics system for research on bell pepper production in greenhouses at the University of Alaska Fairbanks. The nutrients are kept in the blue barrels seen on the left side of the picture. A mixing valve adds them to the water when the pump runs to circulate water through the system.

Nutrient management

A nutrient plan depends on the crop and the growing system. In soil-based systems, compost and/or fertilizers can be added when the soil is prepared and the greenhouse is set up. Additional compost or fertilizer is added as the soil is worked between harvests and crops. Fertilizer can also be added to the irrigation water and provided through hand or automatic watering. In hydroponic systems, the water solution supplies the roots of the plants with nutrients. In aquaponic systems, fish waste may provide some of the nutrients to the plants.

To determine nutrient content, test the soil, water regularly, and obtain recommendations for what nutrients to add. If there is a nutrient deficiency, plants often show specific characteristic symptoms. A guide like the Alaska Sustainable Gardening Handbook can be helpful in diagnosing a potential deficiency.

Staff working with nutrients and fertilizers should be trained in safety–whether the fertilizer is commercially developed or produced through composting on site. The University of Alaska Fairbanks Cooperative Extension Service offers publications on composting, fertilizers and pesticides, and also has a pesticide safety certification program.

Fertilizer

Synthetic water soluble fertilizers are commonly used in hydroponic systems, although organic fertilizers are also being developed. Commercial fertilizers are often mixed with water and applied to plants in soil or peat-based growing systems. In general, it is better to apply a more dilute nutrient solution often than a concentrated fertilizer at less frequency. If there is a nutrient issue, the problem can often be caught in time to take corrective action when a more dilute fertilizer is used.

There is a lot of interest in using organic rather than commercial synthetic fertilizers. Organic fertilizers and compost can be mixed into the growing substrate before planting, added to the soil surface during the growing season, or applied in the form of liquid compost teas or fish emulsions. The methods can also be combined. Organic fertilizers release nutrients as they decompose. The rate by which the nutrients become available may therefore vary dependent on growing conditions, moisture content, and soil temperature. Matching nutrient content with the plant's need and uptake can therefore be challenging with organic fertilizers.

Bags of fertilizer should be organized and stored in a dry location such as a cabinet or closet, away from the humid environment of the greenhouse. Access should be restricted to staff with training in the safe handling of fertilizers. Any spills should be cleaned up immediately.

Compost

Composting is a great way to take plant waste products from your greenhouse and convert them into nutrients for future crops. In a compost pile, organisms such as insects, worms, fungi, and bacteria recycle nutrients from dead plants into humus, an organic matter that can be added back into soil. Compost piles require moisture, oxygen, nitrogen, and carbon for the composting process to take place.

If a compost pile makes sense for your project, be sure to use safe composting practices. First, don't add anything to the compost pile that you wouldn't want on your crops. This includes insect-infested and diseased plants, salty kitchen waste, meat and dairy, dog and cat manure, etc. These materials should either go into a trash bin or be burned. Second, find a suitable location for the compost pile where garden staff can access it easily but it is not in the way of daily operations. Finally, if you are using a shredder or tub grinder to break down plant waste prior to adding to a compost bin, train staff to safely use it.

Some other tips for starting a compost pile or bin:
Compost piles **require oxygen**, so create a first layer of twigs or straw to add drainage and increase airflow to the pile. The compost pile materials should contain a **mix of both carbon and nitrogen**. Materials high in carbon tend to be "brown," such as straw, leaves, paper, and sawdust. Materials high in nitrogen tend to be "green," such as food waste, fish, and cow manure. The goal is to have a mix of brown and green materials and online calculators, such as this one from Green Mountain Technologies, can help determine the best combination of the ingredients available at your location. To increase the surface area of the composting material, **shred plant waste** prior to adding to compost. The compost should be **moist** – not wet and not dry. If the pile is covered, be sure to water it occasionally. **Turn the pile** weekly to aerate it. This step is optional but allows more oxygen to reach the microorganisms responsible for fast decomposition. **New compost materials should be added to the middle** of the pile, not the top. Adding new materials provides an opportunity to turn the pile and aerate it!

Biochar

Biochar is an agricultural amendment produced from wood that is gaining wide recognition within the agricultural industry. It acts as a foundation for soil health, plant root growth, nutrient uptake, water retention, and water filtration. Once added to the soil it becomes a permanent amendment, rarely requiring renewal. Biochar can be readily produced using local wood, an advantage for projects that already have a local biomass supply for heating. For an introduction to biochar, the United States Biochar Initiative has information and links to further resources.

Do you have ash leftover from the biomass heating? Wood ash can provide nutrients for a greenhouse, when applied to plants correctly. See this resource from the Oregon State University Extension Service for more information.

Lettuce grows in a raised bed at the biomass-heated greenhouse at Tok School. The greenhouse manager in Tok, Bonnie Emery, uses compost to add nutrients and structure to the soil in the raised beds. Plant waste is processed in a shredder and added to the compost pile. Bonnie and the school district are currently augmenting their compost program. They built a heated pad for the compost pile in Summer 2016 and plan to add food waste from the Tok School cafeteria to the compost.

Pest management

As you make a greenhouse environment optimal for plants, it also becomes optimal for pests. After all, a greenhouse is a warm, humid environment with no predators. A project team's goal for pests is control – not eradication. Consider the overall health of the greenhouse and how to improve it in general, rather than getting stuck focusing on removing every last bug. As Meriam Karlsson, professor of horticulture at the University of Alaska Fairbanks, puts it, the top three conditions for managing pests:

"Cleanliness, cleanliness, and cleanliness."

Starting and staying clean is the first step to managing pests. Standing water, decaying plants, piles of leaves on the floor all act as hiding places for pests. Cleaning the floor, benches, and windows should be regular tasks on a maintenance checklist. If the floor of the greenhouse is gravel or chips, put a landscape cloth down underneath it to prevent pests from entering the greenhouse through the ground.

In general, if you have a pest problem, research the conditions that are optimal for that pest. Then, focus on eliminating those conditions. For instance, aphids prefer soils with high nitrogen levels. Thorough irrigation and proper fertilization can eliminate the high nitrogen levels and then the aphid population will decrease.

Pests will be a continual problem throughout a greenhouse's life. However, staff will learn to monitor them and adjust practices when there is a problem. And continue to monitor and adjust: with practice, watching for and controlling pest problems will become second nature for greenhouse staff.

Other tips for managing pests:

Freeze-up can be a good strategy. Once a year, in the winter months, allow the greenhouse to freeze. If the greenhouse has pipes, be careful to drain them first – but otherwise, the low temperatures will take care of many bugs, mold, and fungus. When the greenhouse is warmed back up, but before growing plants, is a good time for staff to perform a thorough cleaning.

Heating soil with steam or an oven is another strategy to eliminate pests. Temperatures should be between 140-160 F to kill pests and leave the helpful organisms.

Good soil preparation promotes fewer pests. Send soil samples to a lab for testing (the University of Alaska Fairbanks Cooperative Extension Service can recommend one in your area) and add the missing nutrients to the soil.

Weed early and often. Weeding by hand is tedious but ensures that all weeds are caught. To make this easier, use tools such as a small hoe. Also, keep the surrounding area mowed to reduce outside pests from entering.

Learn to observe common pests so that staff can catch the problem early and address it. Aphids, thrips, and mites are small, but with practice can be seen quickly.

Introducing beneficial pests, such as ladybugs and lacewings, can help to control a pest population. However, this strategy requires constant monitoring – the good bugs require pests to eat, or the good ones will die off too. Also, consider the optimal temperature range for the good bug that you are introducing – is it the same as the conditions in your greenhouse?

Pesticide application also can eliminate pests. Train staff to use pesticides and be sure to store them in a safe, clean, organized location. Many pesticides are non-toxic, and some soap pesticides you can mix yourself with materials from a local grocery store. The Alaska Department of Environmental Conservation has a Pesticide Control Program with information on different products and how to use pesticides safely.

Typical greenhouse pests, such as aphids and thrips, are small! But they get easier to spot, identify, and control with practice.

Best management practices & troubleshooting

A number of systems and processes need to come together to ensure the greenhouse is suitable for plant growth as well as educational activities. To decrease potential impacts on the environment, it's helpful to consult best management practices, which can guide irrigation, nutrient management, energy conservation, organic and inorganic waste handling, composting, pest control methods, and the type of sanitation products used.

Examples of best management practices include how to provide water and nutrients as plants grow and develop. Rapidly growing plants under high light in the summer will need more water and fertilizer than smaller plants just starting out. Matching the amount of water and nutrients to the needs of the plants will reduce waste while still ensuring good growth. Only running lights when the natural light is insufficient and above plants rather than walkways can save electricity and extend the life of the light fixtures.

When equipment or greenhouse systems are not working properly, systematic methods for troubleshooting are needed to identify the problem. For instance, if the greenhouse is not maintaining the desired temperature, you may have to inspect the boiler and follow the flow of heat entering the greenhouse to identify the problem. Check to see if the controller and thermostat are working properly. Other possibilities could be the heating and ventilation system. Heating the greenhouse while still running ventilation can create variable temperatures and waste energy. As seasons change, you may need to make modifications to the heating and cooling regime. Some cooling systems may not be used during the winter, for example, and you need to decide when to turn the systems back on based on outside temperatures and the desired greenhouse conditions.

Driving or stopping by the greenhouse late at night or early in the morning may reveal that a light or fan is running when it shouldn't be. Automatic controllers and timers are labor savors and can significantly facilitate the management of the greenhouse. Although relatively simple to program, it is possible to make mistakes and activate equipment at the wrong time.

The University of Alaska Fairbanks Cooperative Extension Service has a wealth of agricultural publications for every level of gardener. The website contains information on everything from seed starting to making your own fertilizer, and has sample checklists of gardening tasks.

"It's taken a few years to get a grow schedule set up. Parts of it include growing lots of tomatoes in the summer. It's too hot for lettuce in the summer. They have to estimate the number of days until harvest for each thing. The seed package tells you, but it depends on light. So you have to adjust that to your own situation."
– Scott MacManus, Superintendent, Alaska Gateway School District

Horticulture operations and maintenance

This plan is a sample daily, monthly, and annual checklist for a greenhouse with a soil growing system. Of course, the checklists for each project will look different – use this one to get a general feel for the tasks involved in greenhouse operation.

Also, know that while these tasks may seem tedious at first, the tasks will become routine and observation will occur subconsciously. After a few months, staff will "know" the greenhouse. They will walk in the door and know exactly what to expect: how warm and humid it should feel, what noises from pumps or fans they should hear, and how the plants should look.

Daily:

Check and observe plants.

- Water?
- Pests?
- What is ready for harvest?
- What is ready for transplant?
- What requires pruning?
- What requires staking?
- Do any have nutrient deficiencies?

Measure air temperature: Is it in the optimal range for your plants?
Measure relative humidity: Is it in the optimal range for your plants?
Perform a water test.
Check mechanical systems to ensure they have power and are operating according to schedule: the heating and cooling system, fans, and pumps.

"Greenhouses are great! They have lots of benefits, including fresh produce, the ability to experiment, the social and psychological benefit of seeing something growing in the winter, and just watching plants as they grow and change. However, greenhouses are energy intensive and require continuous care."
- Meriam Karlsson, Professor,
School of Natural Resource Management at the University of Alaska Fairbanks

Monthly:

Check supply inventory
Check first aid kit
Clean greenhouse windows
Clean greenhouse floor
Clean irrigation system pipes
Weeding outside/walkways
Staff safety meeting
Clean and repair tools

Annual:

Check heating and cooling systems
Shut down and sterilize greenhouse
Evaluate monitoring records to identify trends
Re-visit daily and monthly checklists to revise and improve them

6

ECONOMICS

PLANNING FOR FINANCIAL STABILITY

6

ECONOMICS
PLANNING FOR FINANCIAL STABILITY

When considering a biomass-heated greenhouse project, it is important to determine whether the project will be financially sustainable. That is, will the revenue generated from the project be enough to cover the operation and maintenance of the system? Will it also cover any required loan payments? It's also important to consider financial sustainability along with the benefits of the project to the community, and to society at large.

Before reading this chapter, think about which perspective and financial goal fit your project. Also, develop the inputs, assumptions, and limitations associated with the project sooner than later as opportunities and decisions will often have budget ramifications.

School/Organization perspective: This perspective only considers the cash flow of the school or organization itself. It will include all direct operating and maintenance costs, produce sales, and any capital costs paid directly or through loans. It does not include grant funds or community benefits.

Community perspective: The community perspective considers everything in the school/organization position and also includes any direct benefits or costs to the community, such as wages earned by harvesting wood, potential health benefits to the community, etc.

Societal perspective: This includes all costs and benefits to society, considering everything from the other two perspectives plus any grant funds used or external factors such as the cost of carbon.

RIGHT: Starter plants await transplant in the Southeast Island School District on Prince of Wales Island.

Financial goals

The financial goals for a particular project depend on the project team's vision and priorities.
However, basic financial health of a biomass-heated greenhouse operation is important even for projects that haven't prioritized earning a profit. Many project's financial goals fall into one of the following three broad categories:

Earn a profit: Making more money than you spend will earn you a profit. Some organizations may want to earn a profit to pay back their initial capital costs; others may want to earn a profit so they can expand their programs. Private owners typically want to earn a profit on the money that they have invested.

Recover your annual expenses: Many organizations will at least need to earn enough money annually for the program to break even. Schools and other non-profit organizations typically have tight budgets and many can't afford to lose money on an annual basis. These organizations may have started the greenhouse for educational purposes, health and/or environmental benefits, or to support the local economy. However, to continue they will have to at least cover expenses.

Limit your losses: The educational, health, and jobs benefits to a community from a biomass-heated greenhouse could be significant. Schools may be willing to consider the greenhouse as an educational investment. Health-focused organizations may decide that the long-term benefits of greater access to fresh produce is worth an annual investment. However, every organization has limits to how much money it can invest. Even in these cases, it is important to plan so that you maximize social benefits while minimizing financial inputs.

Value of education: For schools undertaking a biomass-heated greenhouse project, it is important to consider the educational value of the greenhouse program. What would the cost of a similar long-term, hands-on educational program be for the school? The cost of a comparable learning kit (science lab kits, etc.) can be used as a benefit in the economic analysis if the greenhouse is expected to displace the funding of another educational program. It is important to consider the organization's goals in determining whether the educational value is or is not considered in the economic analysis.

"From my perspective, the biggest challenge has been operating the greenhouse like a business. I'm always cognizant of this goal - we aren't trying to make a profit but we are trying to avoid any losses."
– Scott MacManus, Superintendent,
Alaska Gateway School District

Greenhouse capital costs

Good planning of a suitable design is needed to minimize the initial capital costs while still providing for systems that will support crop productivity to meet market demand. There are many different types of greenhouse structures that projects might want to consider. For instance, high tunnels provide shelter for crops grown directly in the field soil under the high tunnel. They are often a less expensive alternative than framed greenhouses, which are intended for year-round production and have the structure strength to support light fixtures and other equipment. They are often constructed with knee walls, poured floors, and drains.

For detailed information on the greenhouse structure, revisit Chapter 3: Building, which covers building envelopes, ventilation, lighting, controls, and more. For whichever type of greenhouse your team is considering, get cost estimates for different designs and features from at least three different manufacturers or construction companies. Do not forget to ask questions about shipping costs and whether or not local crews could participate in the construction. If possible, talk to other greenhouse operators in your region about which features they like or dislike about their greenhouses. Then, discuss the advantages and disadvantages of each and make a careful decision.

To get an idea of greenhouse costs in Alaska, here are some examples from organizations that have installed greenhouses in the state. Of course keep in mind that costs in your area may be very different.

- The cost of Gothic Arch kits purchased by the Southeast Island School District was $17,550. The school district purchased two at the same time, and shipped them both at once for $4,455.
- The Alaska Gateway School District received a bid for a framed greenhouse with glass windows and stone decorations of $200,000. Ultimately, the district purchased a high tunnel greenhouse for the Tok school at a cost of $18,000 and then paid an additional $5,000 for installation.
- In Tanana, the project team purchased a greenhouse kit for a steel-framed greenhouse for $89,000. This cost included shipping.
- Projects in Alaska can also consider a containerized growing system. These are closed plant production systems in buildings that are similar in size to a shipping container. In Alaska, Vertical Harvest Hydroponics manufactures these systems. An exact capital cost depends on the location and system, but projects considering this option should be prepared for a capital cost of $100,000 or more. This cost includes the container as well as the lighting and growing system already set up inside.

Greenhouse Economics Worksheet: As you go through this chapter, it may be helpful to use the Greenhouse Economics Worksheet to assist you in thinking about the initial capital costs, annual revenue and expenses, and overall profits of your project. A sample worksheet using the Chena Hot Springs Resort greenhouse may help you complete your worksheet.

RIGHT: The biomass-heated school greenhouse in the small community of Kasaan on Prince of Wales Island in Southeast Alaska.

Biomass appliance capital costs

The capital cost of the biomass appliance will depend on how many buildings the appliance is heating. For some projects, the biomass heating system may provide heat to several buildings, such as the school, greenhouse, and teacher housing. For these systems, the initial capital cost for the biomass boiler will be significant. For instance, the Southeast Island School District purchased several GARN cordwood boilers to heat schools on Prince of Wales Islands. They paid $17,000 for a GARN 2000 boiler and $42,000 for a larger GARN 3200 boiler. Shipping for two boilers that arrived together added an additional $12,000 to the capital cost. Projects that utilize boilers such as these will also face installation and plumbing costs, and constructing a building to house the boiler and a shed to store the biomass fuel.

The USDA Forest Service has a Wood Energy Financial Calculator to help project teams analyze the long-term economics of these systems.

Wood Energy Financial Calculator

Some project teams may be looking to utilize extra heat from a biomass boiler already in operation heating other buildings. In this case, the only additional capital costs would be for adding a heat distribution loop to the greenhouse. See Chapter 4: Biomass Heating for options on how to do this and also Chapter 3: Building for considerations on locating the greenhouse near the biomass appliance.

Finally, some greenhouses many have their own dedicated biomass system. In this case, the heating appliance and distribution can be customized to the greenhouse. There are many biomass options for a single building, including pellet or wood stoves, masonry heaters, and cordwood boilers. Depending on the size, these appliances may cost a few thousand to several thousand dollars.

No matter what the appliance, look for one that features low emissions and high efficiency. Take the time to speak with other users of the appliance to find out about the maintenance requirements and operation.

RIGHT: Starter plants can benefit from biomass-heating appliances that provide warm temperatures during the Alaskan spring.

Energy costs

The two main energy costs for greenhouses are heating and electricity. It is imperative to estimate what these costs will be prior to building the greenhouse or purchasing a biomass appliance. Energy auditors, especially those with greenhouse and biomass-heating system experience, can provide an estimate of projected costs to project teams. Project leaders may want to speak with staff from similar projects in the area about their energy costs. Also, consider your project team's financial goal because the annual energy costs will have a large effect on the ability of the project to turn a profit, sustain itself, or limit the need for annual investment.

Heating

Schools should verify that they would actually reap the energy cost savings of installing a biomass system. Rural school operations budgets come from the state and are disbursed to districts. If individual schools save money on energy by installing a biomass heating system there is no guarantee that the school will see those savings. School representatives need to discuss potential biomass projects with the school district and negotiate where the savings will go. And, some school districts may not necessarily be looking for savings. A biomass project that provides a sustainable, local heating solution and reduces reliance on outside shipments of fossil fuels may not have to pencil out financially for a school district to realize other benefits.

What is the cost of locally available biomass? Is the supply steady and long-term? Do prices fluctuate? Project teams should consider how much they will need to pay to obtain biomass and whether or not they need to transport it to their location. Biomass heating systems require ongoing maintenance and operations tasks. While an existing employee may be able to incorporate these into current job duties for a small biomass appliance, larger appliances will require dedicated staff to run. Who will pay for the labor?

When considering the annual cost of operating a biomass system, be sure to factor in the price of the biomass fuel and the cost of operations and maintenance together with potential benefits to the organization, community, or society.

Electricity

Minimizing electricity costs can be important to a greenhouse's bottom line, especially in rural areas where electricity is exponentially more expensive than in urban areas. Some community groups can qualify for a subsidy from the Power Cost Equalization program–check to see if this is a possibility. Another option for those with high electricity costs is to consider a break in growing plants in the greenhouse during the coldest winter months. This strategy is used by many greenhouses in Alaska, and can provide other benefits, such as an opportunity to perform a deep cleaning of the greenhouse to get everything ready for the coming spring.

Lighting: During the winter half of the year, lighting can be expected to consume a large amount of electricity. In selecting light sources for the greenhouse, it is important to consider both the initial capital cost as well as the cost for the electrical operation. The efficiency to convert electrical energy to usable light for plants can vary significantly among light sources such as LEDs versus high pressure sodium lights. In addition, it is not unusual for the energy efficiency to vary depending on the brand or manufacturer of similar light sources such as high pressure sodium fixtures. Deciding on a suitable light source is therefore a multifaceted consideration of cost, energy efficiency, type of plants, production systems, and expectations of improved plant growth.

Since lighting can be a significant cost in operating a greenhouse, you may want to consider growing plants with low light requirements or even shutting down the greenhouse during months of least natural light. The greenhouse at Tok School does not use supplemental lighting. For most school greenhouses, growing plants during the winter is likely a goal and at least some supplemental lighting will need to be provided.

Fans and other greenhouse equipment: Exhaust and horizontal airflow fans are needed to control temperatures and maintain a uniform optimized growing environment. Exhaust fans expel hot air while colder outside air is brought in through louvers or vents. For the system to work well, louvers and vents are motorized and synchronized with the exhaust fans. Other techniques such as fan and pad evaporative cooling or fogging systems may be needed to further reduce the greenhouse temperature. Natural or passive cooling builds on the concept of warmer air rising to be removed through roof vents. Horizontal airflow is desirable to maintain a more uniform temperature environment, mixing of carbon dioxide and a more evenly distributed relative humidity.

Depending on the production system and setup of the greenhouse, various pieces of equipment will use electricity. In a hydroponic or aquaponic greenhouse, for instance, several pumps are usually needed to maintain water flow, control dissolved oxygen levels and supply nutrients. The greenhouse may also be equipped with energy or shade curtains to reduce heat loss during the night and solar heat load during the day. Controllers, sensors, alarms and computers are dependent on a reliable electric energy source to properly monitor, adjust, maintain and run the greenhouse.

LEFT: Corbin Creek Farms in Valdez utilizes biomass-heated high tunnel greenhouses to increase the length of their growing season.
Photo courtesy of Corbin Creek Farms.

Supply and labor costs

Due to the wide range of shipping costs found in Alaska, supply costs will differ significantly from region to region. Labor costs for operations and maintenance can be significant, and will also vary with the type and size of production system, labor provided by students and volunteers, and the hourly pay scale used in the community. As a general rule of thumb, cold-climate greenhouse consultant Jeff Werner estimates that greenhouse supplies account for approximate 20 percent and maintenance costs for another 20 percent of the annual greenhouse budget.

Supplies: A variety of greenhouse supplies will need to be purchased annually. Since the cost can be significant, it is important to consider these costs in determining the yearly budget. The cost and quantities will vary with the size of your greenhouse, type of crops produced and shipping. At a minimum, you should obtain estimates for seeds and plant materials, growing substrates, fertilizers, pest management products and beneficial insects, and packaging supplies (bags, containers, boxes, etc) for distribution and marketing of grown products.

The Alaska Center for Energy and Power and the Southwest Alaska Municipal Conference both published studies (links here and here) estimating greenhouse economics based on the capital and operating costs from the Chena Hot Springs greenhouse. The annual costs for material inputs and accessories for the Chena greenhouse were $47,211 for a 4,320 square foot greenhouse operation. This equates to $10.93 per square foot annually for supplies, which is a reasonable estimate to use until you have determined the specific costs for your location. In the Greenhouse Economics Worksheet, you can either use this estimate or enter your own costs.

Labor: It is important to consider who will be doing the operations and maintenance labor for the greenhouse and what the labor will be. What proportion of the labor will students be contributing? What about educators? Who will continue operating and maintaining the greenhouse when school is out?

Students, educators, and volunteers are often willing to assist with plant and crop-related activities such as seeding, watering and harvest, while mundane tasks such as daily cleaning are not being completed. Planning labor for daily upkeep, such as cleaning by a janitor, in addition to the operation and management can make a big difference in the success of the greenhouse. Another issue for consideration is who will continue operating and maintaining the greenhouse in the summer and during holiday and spring breaks?

It is also useful to take into account the background gardening knowledge that students, workers, and volunteers may have. Operating a greenhouse is a knowledge-intensive endeavor, and it may be necessary to spend money to provide training and factor in time for workers to learn the skills necessary to effectively grow produce. Will Anderson, President of the Kikiktagruk Inupiat Corporation, shared about his organization's experience in rural Alaska with a containerized growing system: "Kotzebue is not a traditional agriculture location - historically, we are hunter-gatherers. So our workers needed to develop agricultural skills. The Vertical Harvest Hydroponics unit has one employee, and he came in with very little horticulture experience so is learning as he goes."

"Even at $1.80 per gallon of fuel oil, a cheap price, we are showing that we can save money by heating with wood. So even at a dollar eighty, these systems at least broke even but more than likely they show on the positive side. So all things being equal, all of that money stays in your community. So you are paying a local firewood cutter, a local business owner, you are paying a local sawmill operator for the wood and biomass. You are paying someone locally to pack the wood and paying someone locally to stoke the fire. So that creates that multiplicity effect of dollars staying in a small town and in rural Alaska, every dollar you can keep in your community as opposed to shipping out, goes around and around something like ten times more. So the person earning the wage can pay their utility bills, buy groceries and stay in the community."

– Karen Petersen, Chair,
Alaska Wood Energy Development Task Group

Market

In Alaska, your market is your community. It's important to take the time to know that market and take the time to communicate with them. Successful food businesses will find a balance between what they can and want to grow, and what they can sell in a profitable way. Before the first seed is planted, the project team should consider their future market. It may be appropriate to perform a market survey, or talk with stakeholders in that market, to find out what produce and prices they feel are appropriate.

The biggest markets in rural Alaska are generally schools, senior centers, and health care facilities. These larger institutions have regular funding and are consistent buyers. If you are considering selling produce to them in the future, go meet with the person in charge of buying food for the institution. Find out if they will be willing to purchase produce from your greenhouse. How do the cooks feel about using local produce in their recipes? Will it add processing time for them, or is there something your project staff can address to ensure a smooth transition?

For projects to be sustainable, the market needs to be diverse. Even with a large, committed customer such as a school or hospital, other market avenues are necessary to fill in gaps, such as when school is out of session, or provide an opportunity to grow a larger variety of produce. Consider other potential buyers in the community. Would individuals sign up for a Community Supported Agriculture (CSA) program? CSA programs provide produce directly to consumers throughout a growing season for an upfront fee. Are there restaurants or hotels that would like the opportunity to cook with local vegetables? Or can you rent a booth at a farmer's market or set up a stand at the greenhouse for community members to stop by? Think about whom in the community shares a commitment to the goals in the project's vision, and go talk to them.

Finally, invest in your market! One way to increase demand for your product is to tell your story. If produce is being used in the school kitchen, hang posters in the cafeteria so students know where their food came from. Provide restaurants, hotels, and hospitals with a vision or logo that they can add to their menu. If the project doesn't have a logo, see if students in a business class would be willing to make one, or apply to use the Alaska Grown logo available from the Alaska Division of Agriculture. The project team might also consider sharing the story of building the biomass-heated greenhouse in a local newspaper article or radio interview. Additionally, there are state and national programs that may be able to help provide materials and funding for marketing. For example, the Alaska Division of Agriculture has a list of marketing resources relevant to our state and the USDA has a variety of grants, research, and materials available through their Agricultural Marketing Service Division.

> "It's important to grow your market. One way to do this may be to hold cooking classes in local communities to show people how to cook new vegetables. If you can increase your market it helps you to be able to grow a diversity of vegetables."
> - Scott MacManus, Superintendent, Alaska Gateway School District

Kikiktagruk Inupiat Corporation in Kotzebue sells lettuce at the hotel, hospital, and supermarket. Photo courtesy Kikiktagruk Inupiat Corporation.

Sales

After identifying a market, there are practical considerations to address, such as what vegetables to grow, how many of them to grow, pricing, and distribution. Each of these decisions will have market implications and could add annual costs to your budget. For projects looking to make a profit, an upfront customer survey will help to address some of these questions. For other projects, it may be appropriate to take a strategy of trial and error. In either case, the project team should set aside a time each quarter to look at costs and sales and make any necessary changes to keep everything going smoothly.

What produce to grow: Every square foot of greenhouse space is valuable. Horticulture consultant and Chena Hot Springs Greenhouse co-designer Jeff Werner recommends considering the following questions when thinking about what to produce:

1. Harvests: Can you grow to maturity and harvest a crop more than once in the season?
2. Yield: Will you only get a single plate serving out of the space at harvest time? You can grow a lot of some crops in a small amount of space, like cucumbers and lettuce.
3. Demand: What crops are desired by your customers?

Of course, projects not focused solely on profit will have their own priorities for choosing a variety of vegetables. These might include allowing students to choose their own crops, growing ready-to-eat vegetables such as lettuce for students to try, or growing herbs for a culinary arts class.

Balance the project vision with the financial goals when choosing crops to grow. And of course, be open to change if something isn't working. It's important to keep records of crop type and quantity, harvest schedules, and sales so that project staff can compare the differences between crops and make adjustments for the future.

Pricing: There are many methods to set prices. Ideally, a project team would set prices based on what the cost is to produce each pound of product. How much do seeds and growing materials cost? What are monthly operating expenses? What about transportation costs? To set pricing, a team would look to recover costs and then perhaps add in a margin of profit.

However, this method of setting prices may not work for your market. For instance, schools operate on a limited budget and have to make a set number of meals each day to ensure students receive adequate nutrition. When selling to schools, the best option is to price the produce at the school's current cost of purchasing food. The school's current cost should include the cost of transporting food to the community, which should make the price more competitive for the local growers.

Another consideration when setting prices is to look at prices for similar produce in your area. Consumers may be willing to pay more for locally grown produce, and again, a market survey could help determine how much more you could charge. For instance, a market study conducted by the University of Alaska Center for Economic Development found that many buyers in Interior Alaska were willing to pay significant price premiums for locally grown produce-- thirteen percent of buyers were willing to pay 26% or more for local produce and fifty percent of buyers were willing to pay a premium of 10-25% (Nguyen, 2014).

Distribution: Distribution of produce can be difficult in the sparsely populated, remote areas throughout Alaska. In most rural areas, the majority of the produce will need to be purchased and consumed within the immediate town itself. Even then, it is important to think about how to get the produce from the greenhouse into the hands of individual and institutional customers. What packaging materials and containers can be used? How many can a staff member carry? Do these containers fit nicely on the shelves of the local supermarket? Be intentional in decisions so that the distribution process runs smoothly.

For those wishing to transport produce out-of-town, brainstorm potential options, consider the cost of each, and ask the community and project stakeholders for ideas. For instance, some projects in Alaska distribute vegetables in the extra room in vehicles making a trip for another purpose. The Alaska Gateway School District sends vegetables to district schools in the cars of itinerant staff, such as maintenance personnel and special education teachers. In fact, it is part of their job description! Other greenhouses have taken advantage of planes with empty cargo bins and the trucks of telecom workers to transport produce to different communities.

A bell pepper grows in a hydroponic system at the University of Alaska Fairbanks.

Calculating economic feasibility

The Wood Energy Financial Calculator is the best resource for analyzing the economics of a biomass system that will heat a building other than the greenhouse. For the actual greenhouse economics, including a potential small biomass appliance used just for the greenhouse, the Greenhouse Economics Worksheet is a tool that can be used to help you determine whether or not your project will be self-sustaining. There is also a sample worksheet that has been filled out using the Chena Greenhouse as an example to help you. The following sections describe how to properly use the tool.

General Characteristics: Enter the proposed size of the greenhouse and choose a region and city from the drop-down menus, which will bring up the location construction cost multiplier used by the Alaska Department of Education. When determining the project lifespan, consider the estimated life of the most expensive materials being used as well as a realistic expectation for how many years the greenhouse will likely be used. Typically life cycle costing is not done for periods longer than 25 years.

Capital Costs: First, use the greenhouse structure calculator to estimate the cost of your structure. Then enter your estimated capital costs for the remaining equipment needed. If you don't have quotes for your local costs, look up Anchorage prices and multiply them by the location factor found on the General Characteristics tab.

Annual Costs: Estimate your annual production costs here either by entering the cost per unit and the estimated number of units needed.

Revenue: Estimate your sales and non-sales revenue on this tab. Use sales from prior years if available, otherwise consider asking greenhouse producers in similar conditions. Additionally, this sheet can be used at the end of Year One to track the revenue per square foot of each type of plant and compare which ones were the most profitable.

Outputs: This tab shows the results of the economic analysis. The *simple payback* is the total number of years of operation required to pay back the capital costs of the greenhouse. The *life cycle savings-to-investment ratio* shows whether the project will be cost effective over the life of the project-- if the result is greater than 1, the profits over the life of the project will have paid back more than the initial capital costs, in inflation-adjusted dollars. The *net present value* shows the total profit over the life of the project (including capital costs), in current dollars.

The outputs page also has results for several *sensitivity analyses*. These show you the economic results for several different scenarios that you may face: higher than expected capital costs, revenue that is more or less than your expectations, and annual costs that are 20% higher or lower than your estimates. This allows you to think about how important each of these factors is for your planned project.

"Pay attention to the cost-drivers in the community. In Kotzebue, energy and labor are the two biggest costs...You have to sharpen your pencil and do the math. How many lights do you have? How long are they on? How much does that cost? What do you pay for labor? My best advice is to pay attention to what the costs will be in your community."
- Will Anderson, President, Kikiktagruk Inupiat Corporation, above right with Alaska Governor Bill Walker in 2016
Photo courtesy Kikiktagruk Inupiat Corporation.

7

FUNDING

STARTING AND SUSTAINING A GREENHOUSE PROJECT

PRECEDING PAGE: A student sells lettuce from the greenhouse in Thorne Bay on Prince of Wales Island.

Securing funding can be one of the most difficult aspects of any enterprise. For biomass-heated greenhouses, total financial backing will rarely come from a single source. Instead it will be up to the project team to create a patchwork of funding resources that best suit the project. For this reason, be sure to recruit someone with fundraising experience to serve on the leadership team. With funding, be ready to look to diverse sources and be creative!

"We have really tried to go after a diversity of funders. We've found the thing that works best is funders who are in Alaska. It's really hard to sell this idea and have people get a good understanding of what the challenges are even if they are from neighboring Washington and Oregon."
- Priscilla Goulding, Federal Programs and Grants Manager, Southeast Island School District

Reaching your project funders and supporters

Before searching for external funding sources, it's important to have a few steps in the planning process already complete. An implementation plan, partnerships, and community support all demonstrate the team's commitment to the project and potential for success. Approach funders with materials summarizing the goals and highlights of your project plan, letters from partners, and demonstrations of community support, such as resolutions from a city or tribal council or letters from local businesses and citizens.

Implementation plan: Having a project plan is a crucial component of a successful project, showing financial backers the practicality of your project and your commitment to success. Stating project goals clearly allows funding organizations to assess the compatibility of your project with their mission and resources. Having a detailed, itemized list of project costs helps potential financiers assess where they can best fit in.

Partners: For certain businesses and organizations, an ongoing partnership with a greenhouse can be mutually beneficial. Look for businesses and organizations that can either make use of your produce in exchange for goods, services, labor, or organic waste that your greenhouse can use for compost. Partnerships with individuals can also strengthen community engagement and investment in your biomass-heated greenhouse; for example, organizing a compostable-materials pickup in your neighborhood to provide a cheap source of compost or advertising your need for scrap material. Every community has something to offer, and creativity can pay off. The more integrated your greenhouse is with the local community, the lower your costs can be.

Community support: Creating relationships and partnerships within the community before searching for funding can strengthen your application. Letters of support from a broad range of organizations demonstrate community investment in the project. You should also consider identifying potential drawbacks (for example, increased traffic from trucks transporting cordwood to a wood-fired boiler) and problemsolving with those who may be affected. Including the results of such discussions can strengthen both your application and the community appeal of your project. It can also help avoid pitfalls that could eventually stop your project from moving forward.

The community of Kake builds raised beds to expand their growing capacities.

Capital funding

Finding capital funding for a biomass-heated greenhouse project can be daunting. Much of the funding will need to come from the project organization and community. External funding sources require financial commitment, such as a down payment for a loan or match for a grant application.

If the project team does pursue a grant or loan, be prepared for a formal application process that can require a significant amount of time and effort. Additionally, many grant programs are highly competitive, so it is worth considering other funding opportunities, such as loan programs and partnerships with Alaska Native corporations and nonprofit companies. In all cases, it is good to contact a funder's program officer before preparing an application, as they can provide useful guidance on determining which funding opportunities are the best match for you.

Other chapters in this handbook can help you determine the capital, energy, and operations and maintenance costs required to start a project.

It is important to remember that money is not the only form of capital that can help your project and lower your out-of-pocket costs. Materials, labor, goods, and services can be offered by many organizations and businesses in the form of "in-kind" contributions, in exchange for things that often cost little to nothing to you. Consult your itemized budget. Anyone you could imagine doing business with once your greenhouse is in operation is a good place to approach for help.

A sampling of produce grown in Moby, the Mobile Greenhouse. Moby visits communities in Southeast Alaska to serve as a stepping stone to local foods, hands-on cultivation, and interdisciplinary curricula. It grew out of a partnership between several organizations: Grow Southeast, Haa Aani LLC, Sustainable Southeast Partnership, Nature Conservancy, Sitka Conservation Society, University of Alaska Southeast, and the Juneau School District. The partnership gave the project ample support throughout Southeast Alaska.

For additional info on starting a biomass-heated greenhouse, check out:
Chapter 3: Building
Chapter 4: Biomass heating
Chapter 5: Growing

Goods, services, and expertise
- **Plant nurseries:** seedlings, flats, plants, gardening goods, expertise
- **Hardware stores:** tools, building materials, construction expertise
- **Lumber companies:** building materials
- **Landscapers:** plants, soil, fertilizer, cleared trees for biomass fuel, expertise
- **Equipment rental:** heavy equipment rentals
- **Waste disposers:** compost materials, miscellaneous discarded debris
- **Garden clubs:** gardening goods, gardening services, expertise
- **Local farmers:** gardening goods, waste materials for compost, expertise
- **Local restaurants:** compost materials, market partnership
- **Cooperative Extension Service:** volunteer coordination, expertise

Labor volunteers and trainers
- **Volunteering organizations:** Lions Club, Kiwanis Club
- **Schools/universities:** K-12 schools, UA campuses
- **Local professionals:** Plumbers, builders, heating contractors, farmers

Education development
- **Local schools and boards:** market partnership, curriculum development, volunteers
- **PTA/PTO groups:** volunteers
- **Local libraries:** curriculum development, book donation

Lettuce growing in a hydroponic system in a biomass-heated greenhouse in the Southeast Island School District.

Sustaining funding

You should not wait to figure out how to sustain a biomass-heated greenhouse until after it is built. In fact, many potential funders will want to know your plan for sustaining operations before they release capital funds. The avenues available for sustaining funding will depend on the greenhouse ownership, location, scale, and other factors. It is important to put together a plan that makes sense for your team.

Sales:
There are many venues for selling produce in Alaska, ranging from direct sales from the greenhouse, selling to schools and hospitals, selling to local restaurants, and selling at farmer's markets. The largest scale operations, such as Bell's Nursery in Anchorage, have the option of selling at large grocery store chains. Sometimes it pays to create your own special venue or capitalize on a holiday, as Palmer High School does by selling flowers for Mother's Day and having special sales events from the back of trucks provided by volunteers.

In rural Alaska, schools and hospitals can provide a steady market. While they may not be able to pay a premium for local produce, there are programs that can help them purchase local food. For instance, USDA's Local Food Procurement guide is one resource that explains how schools can purchase local food within the existing regulations. Another good approach is to match their existing cost for produce from a vendor, and make sure to work with them on the amount and type of produce that work best for them.

Donations:
Not all methods of sustaining a biomass-heated greenhouse need to be from cash sales. Donated items and labor can be very helpful. For instance, school biomass-heated greenhouses face the hurdle of summer maintenance when students are on vacation and teachers are off contract. Wood-fired appliances may need weekend operation. Volunteers can help with watering, weeding, chopping wood, and all the other necessary maintenance tasks in exchange for harvesting their own produce over the summer as "payment." Some schools in Alaska have used farm volunteer programs such as World Wide Opportunities on Organic Farms to bridge the staffing gap in summer.

Similarly, communities offer possibilities for donations. For instance, staff might maintain an ongoing "wish list" on a website for people to view and contribute. Taking the time to meet with store and restaurant owners and explain the project goals can also lead to ongoing donations. For instance, a restaurant might be able to provide food waste for the compost pile. Or, the greenhouse manager at Palmer High School, Don Berberich, took the time to talk to local commercial greenhouses. He explained that one of the goals of his classes was to train students to work at and buy from local greenhouses, and asked for their advice. In addition some greenhouses have donated leftover supplies, such as automatic seeders and pots that the greenhouses were phasing out.

Fundraising:
Another method of supporting ongoing operation is with a good old-fashioned fundraiser. It's a way to not only bring in cash but also show off your success. Consider throwing an open house, a spring planting party, or a harvest party each year. Such gatherings can showcase a project, give the community an opportunity to ask questions of project staff, and let individuals know how they may contribute to the project's continuing success.

Students are involved in every step of the greenhouse project at the Prince of Wales school, from selecting what to grow to stoking the biomass wood boilers to selling and marketing the produce.

Palmer High School has a greenhouse that is used for a 'greenhouse production' class each spring semester. Students in the class choose what and how much to plant as they learn about marketing, logistics, and horticulture. In May, the students sell the plants they have been growing to the community. Half of the proceeds are directed back into the greenhouse program, and the other half funds travel to attend a national Future Farmers of America convention each fall.

Photo courtesy Palmer High School.

Communication & marketing

The need for community outreach does not end after a biomass-heated greenhouse project has been funded, built, or even once produce is harvested. It is important that the community knows where the biomass fuel comes from, where your produce goes, and what the project provides. Keeping a visible presence helps maintain and grow community buy-in.

Methods for communication will vary depending on the circumstances. Look at the strengths of your project and community to find a way to market your project.

For example, if produce is being incorporated into a school lunch program, make sure students know local produce is being served on their plates and where the biomass to heat the greenhouse came from. Perhaps student labor helped chop cordwood or harvest the produce. Share these facts by placing posters in the cafeteria, writing a story in the school newsletter, or making a documentary video for the school assembly.

If the produce is being featured in local restaurants, ask them to advertise it on their menus and elsewhere within the restaurant. Art and journalism classes could create posters and logos for this purpose.

Local media can be helpful for announcing key events, and social media is a common tool for keeping visible with small updates. Again, is there a teacher at school interested in creating content for a story, letter, poster, or video through their curriculum?

Not everyone has a passion for marketing, so don’t hesitate to seek out support if it’s not well covered within your greenhouse project team. Local or statewide non-profit organizations may be able to help tell your story and keep your produce in the mind of your community and region. School districts may be able to provide training to teachers interested in gaining experience, or hire new recruits with this experience in mind.

Don’t forget to keep your project funders and supporters in the loop on what you have accomplished with their help. Never forget to say “thank you” to those who helped make the greenhouse a reality. Many will appreciate formal recognition of their contribution, whether in the form of their logo on a poster, a plaque on the greenhouse site, or publicity in local media. Having a newsletter or taking the time to contact them each year will keep them informed of your progress and share opportunities to stay involved.

Lettuce grown in the C-GRO unit when located at Glennallen High School raised operating funding through local vegetable sales. A Skills USA club at the school was in charge of daily operations, with students in the club maintaining and firing the boiler, running the hydroponics system, and processing and packaging vegetables. The club sold vegetables to Glennallen residents and restaurants in Valdez.

Photos courtesy Copper Valley Development Association.

Known Funding Resources

Many grants and loans available to biomass and greenhouse projects are awarded based on intended goals and demonstrated need. Depending on the role you envision for your biomass-heated greenhouse, there are many options available through federal, state, and tribal organizations.

Also, research local and state foundations that have similar priorities to your project, and do not be afraid to schedule a meeting with a community bank or credit union. Local lenders have many advantages: they are familiar with local challenges and opportunities, are invested in the community, and have staff that can meet with the project team in person to discuss financing options.

The following list of potential funding sources is not comprehensive, and will change after publication of this handbook. It is merely a starting point as you search for grant and loan programs. Ask other project leaders about their funding sources and consult representatives from local, state, and national organizations about their resources as well.

Biomass Utilization Grants:

USDA Forest Service Wood Innovations Program

This grant program seeks proposals to expand and accelerate wood energy and wood products markets throughout the United States to support forest management needs on National Forest System and other forest lands.

Alaska Energy Authority (AEA) Renewable Energy Fund

The Alaska Renewable Energy Fund provides benefits to Alaskans by helping communities across the state reduce and stabilize the cost of energy. The program is designed to produce cost-effective renewable energy for heat and power to benefit Alaskans statewide. Funds may be used for feasibility studies.

Education-Based Grant Sources:

USDA Farm to School Grant Program

The Farm to School grant assists entities in implementing farm-to-school programs that improve access to local foods. Applicants must either have plans to work with schools on developing broad-reaching support services for farm-to-school initiatives, or must support trainings that strengthen farm-to-school supply chains and/or provide technical assistance in the area of local procurement, food safety, culinary education, and/or integration of agriculture-based curriculum.

Team Nutrition Training Grants

These training grants offer funding to agencies to establish or enhance programs to improve children's lifelong eating and physical activity habits, and/or supporting the implementation of USDA's nutrition requirements and the Dietary Guidelines for Americans in meals served in schools and child care institutions.

NSLP Equipment Assistance Grants for SFAs

The USDA Food and Nutrition Service awards equipment assistance grants to eligible school food authorities (SFAs) participating in the National School Lunch Program (NSLP).

Several varieties of lettuce grow in a biomass-heated greenhouse in the Southeast Island School District. Project teams should similarly search out a variety of funding sources to start and sustain their project.

Beginning Farmer and Rancher Development Program-
This program provides grants to organizations for education, mentoring, and technical assistance initiatives for beginning farmers or ranchers. The program funds three types of projects: Standard Projects (beginning farmer/rancher training, education, outreach and technical assistance initiatives), Educational Enhancement Projects, Curriculum, and Training Clearinghouse.

Greenhouse Planning/Implementation Grant and Loan Sources:
Local Food Promotion Program
This program offers grant funds with a 25% match to develop and expand local and regional food business enterprises, to increase local food consumption, and to develop new market opportunities for farm and ranch operations. There are two types of project applications: planning grants and implementation grants.

Federal State Marketing Improvement Program
This program provides matching funds to State Departments of Agriculture, State agricultural experiment stations, and other appropriate State agencies to assist in exploring new market opportunities for U.S. food and agricultural products, and to encourage research and innovation aimed at improving the efficiency and performance of the marketing system.

USDA Business & Industry Loan Guarantees
This program bolsters the existing private credit structure through guaranteeing loans for rural businesses and allowing private lenders to extend more credit than typically feasible.

USDA Rural Business Development Grants
This is a competitive grant designed to support targeted technical assistance, training, and other activities leading to the development or expansion of small and emerging private businesses in rural areas that have fewer than 50 employees and less than $1 million in gross revenues. Programmatic activities are separated into enterprise or opportunity type grant activities.

USDA Value Added Producer Grants
This program helps agricultural producers enter into value-added activities related to the processing and/or marketing of bio-based, value-added products. Generating new products, creating and expanding marketing opportunities, and increasing producer income are the goals of this program.

USDA Rural Cooperative Development Grant Program
The primary objective of this program is to improve the economic condition of rural areas by assisting individuals and businesses in the startup, expansion, or operational improvement of rural cooperatives and other mutually owned businesses through Cooperative Development Centers.

USDA Farm Storage Facility Loan Program
This loan program provides low-interest financing for producers to build or upgrade farm storage and handling facilities.

Innovation/Research Grant Sources:
Western Sustainable Agriculture Research & Education (SARE) Farmer / Rancher Grant
SARE's Farmer / Rancher Grant provides the opportunity for farmers and ranchers to conduct on-the-ground research and education, conduct experiments that lead to more sustainable practices, and create educational outreach plans to disseminate knowledge to others in the Western SARE region.

USDA Agriculture and Food Research Initiative
These grants are awarded to organizations that support research in six Farm Bill categories: plant health and production and plant products; animal health and production and animal products; food safety, nutrition, and health; bioenergy, natural resources, and environment; agriculture systems and technology; and agriculture economics and rural communities.

Community Development:
USDA Community Facilities Direct Loan & Grant Program
This program provides affordable loans and funding to develop essential community facilities in rural areas. An essential community facility provides a necessary service to the local community in a primarily rural area, and does not include private, commercial or business undertakings. Funds can be used to purchase, construct, and/or improve essential community facilities, purchase equipment and pay related project expenses.

Extra Resources:
School Greenhouses
A list of possible grants for building school greenhouses.

Pacific Region Bioenergy Partnership
The Partnership encourages the deployment of biomass energy technologies by assisting in technology transfer, removing barriers to biomass energy production, and providing technical assistance. The Partnership is managed by the U.S. Department of Energy Western Regional Office.

Procuring Local Foods for Child Nutrition Programs
This guide from the USDA, covers the variety of ways that schools can purchase local food, such as food grown in a school garden, in accordance with regulations.

8

LEARNING

EDUCATION FOR STUDENTS, STAFF & THE COMMUNITY

8 LEARNING
EDUCATION FOR STUDENTS, STAFF & THE COMMUNITY

PRECEDING PAGE: Horticulture classes at the University of Alaska Fairbanks conduct experiments in the greenhouses located on the campus.

Even before they are up and running, biomass-heated greenhouse projects present educational opportunities because they require hands-on learning and skills in so many different disciplines. Topics range from basic science, such as biology and energy, to electives like marketing, finance, and cooking. Biomass-heated greenhouse projects also include lessons in entrepreneurship and social enterprise.

Hands-on agricultural experience can increase student consumption of fruits and vegetables. This has been shown by several studies on different age groups such as McAleese & Rankin 2007; Morris et. al., 2002; Morris, Briggs, & Zidenberg-Cherr 2002; and Langellotto, G. & Gupta, A., 2012.

Using a greenhouse and/or a biomass project gives schools an opportunity to offer interdisciplinary education in business, maintenance, construction, agriculture, energy, and marketing. Students learn job skills as well as valuable experience in customer service, reliability, and problem solving.

Finally, these projects promote sustainable communities. A biomass-heated greenhouse can act as a training ground for workers in local biomass and agricultural industries. The produce from the greenhouse stays in the community – as a direct product (locally-grown vegetables for a cafeteria), or the starter for a cottage industry (using herbs to create infused olive oil). The use of locally sourced biomass in a greenhouse gives area biomass producers another customer, and the sale of produce keeps money circulating in the local economy.

“We’re trying to give kids the skills they need to eat better, grow their own food, possibly start a business if they want, and be able to stick around on the island if that’s what they want to do.”
– Colter Barnes, Principal, Southeast Island School District

“I think the work skills are the most valuable. [Students] have to show up on time – the product is dependent on them. They have to have good customer service skills, attendance, they have to be there and be responsible for those plants. They can’t walk out the door until they turn around and look at the greenhouse and ask themselves, ‘Will everything live until tomorrow?’ It is a good responsibility for them to learn.”

- Megan Fitzpatrick, Teacher, Southeast Island School District

In the Southeast Island School District, biomass-heated greenhouses provide produce for the schools and community, and teach students workplace skills. Students gain firsthand knowledge of the entrepreneurial nature of a local business as they work side-by-side with teachers operating the biomass heating systems and greenhouses. Teachers can also use the greenhouses to complement their curriculum.

Getting started

The first step to using a biomass-heated greenhouse in education is for the project team to make a plan. As with the overall operations plan discussed in Chapter 2, this plan will require review by stakeholders and plenty of revision. Depending where "education" lands on the list of overall priorities for a project, implementing an educational component may not occur for a few years – especially for production greenhouses that are trying to reach financial stability before incorporating an educational component into the project. On the other hand, projects with education as a primary focus will plan to develop the curriculum at the project start and may see production take a backseat as teachers become comfortable with using the biomass-heated greenhouse as an educational resource.

The plan should specify important components of a curriculum to serve as a guide. The project team should consider local resources when drafting the plan, and tailor its goals and procedures to fit the particular community and organization. Here are some questions to consider when drafting a plan:

What is the overall vision for the educational program? Is the goal to focus on production but also offer a few tours each year? Is the project going to be used by teachers of all subjects at a school?

Who will oversee the educational program? If someone has questions, needs a key for access, or has an idea for an experiment, whom do they talk to?

Who is the audience? Are you educating students? Community members?

Who is teaching? Will teachers in a school be using the greenhouse in their regular classes? Will a Cooperative Extension Service agent use the greenhouse to hold workshops?

What are initial objectives for an educational program? Are these objectives SMART, as discussed in Chapter 2?

What resources are already available for education? Do the boiler room and greenhouse have adequate space and an employee who can give students a safety orientation? Are there plenty of tools for students to use? Do you have a curriculum that teachers can use as a starting point?

What resources are needed? Resources might include items such as tables or extra tools, training for future teachers, advertising to recruit students, and funding.

How will the program be funded? Will the school district pay for teachers to attend a workshop about agricultural topics? Will sales from produce pay for extra educational equipment? Will there be a charge for classes for the community?

Training teachers

Teachers need to have training and resources in order to incorporate a biomass-heated greenhouse project into existing classes and creating new courses around the project. It's important to find an ongoing training method that will work for existing staff, new staff, and the local community. The implementation plan or the specific educational plan is a good place to specify how training will occur. Some ideas for training educators include:

Hiring individuals with prior experience: Many school districts, including the Southeast Island School District and Tanana City School District, hire new staff with the biomass-heated greenhouse in mind. This ensures teachers are open to incorporating the biomass-heated greenhouse into lesson plans.

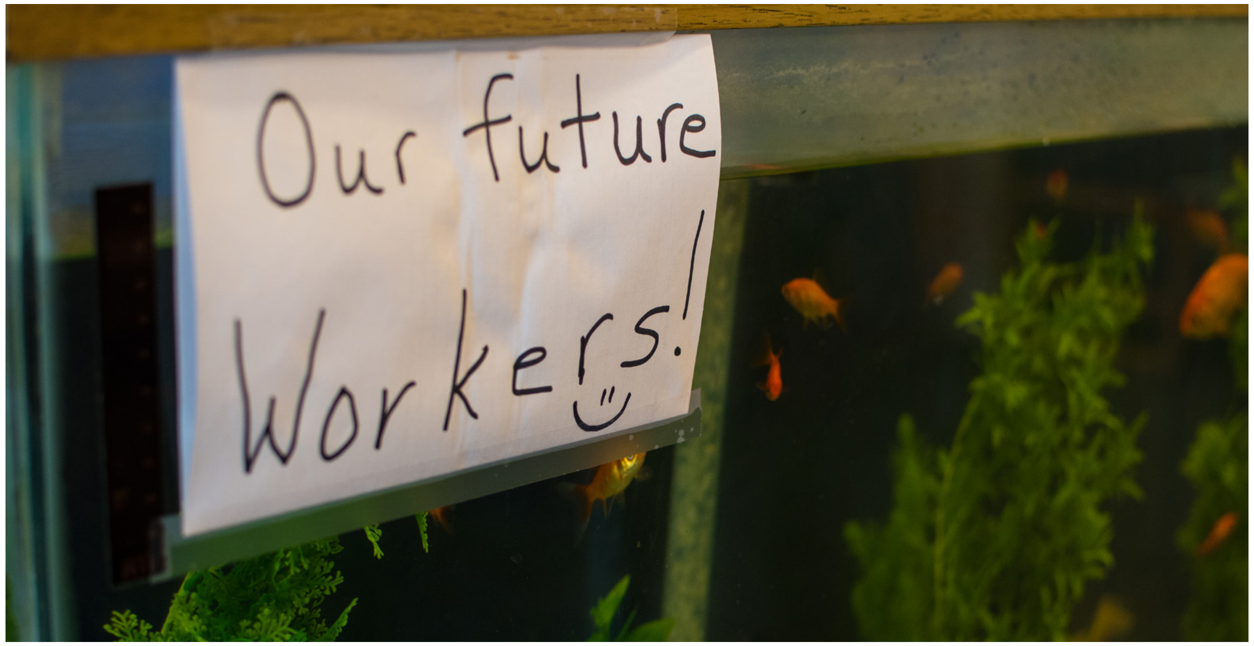
Continuing education: Teachers require continuing education to maintain their certifications. Many national organizations offer teacher training programs and some are listed in the table at the end of this chapter. Alaska has a great resource for teachers working with greenhouses to learn basic gardening skills–the University of Alaska Fairbanks Cooperative Extension Service offers an online Master Gardener course that provides continuing education credits. Teachers enrolled in the course can earn required volunteer hours by creating lesson plans on gardening topics, which are shared on the course blog. Another Alaska-specific resource is the course in Agricultural Literacy for Alaskan educators offered by the Fairbanks Soil & Water Conservation District's Alaska Agriculture in the Classroom program.

Staff positions to facilitate instruction: If funds allow, an organization can hire an individual to focus on implementing an educational program. In a school district, this may be a designated staff member that can find and adapt curriculum to the particular school, serve as a resource for questions, and hold training sessions for teachers. This individual might also be in charge of conducting safety trainings, searching for funding for educational programs, facilitating weekend workshops and tours for the greater community, and other tasks that might be difficult to fit into existing job duties for other staff.

Form chapter of a national organization: National organizations like the National FFA Organization, SkillsUSA and 4-H offer existing frameworks that can be implemented by local chapters. These organizations have curriculum and activities, offer resources such as scholarships, conferences and competitions, and provide an opportunity to network with other chapters throughout Alaska, the United States, and the world.

RIGHT: Megan Fitzpatrick, a teacher at Southeast Island School District, switched the greenhouse at her school from hydroponics to aquaponics after attending a conference in California. As she said, "I wanted to grow beyond just lettuce and dive more deeply into the process. I discovered the concept of aquaponics at a conference, read an article, and felt it would be better for students."

In addition to being a school principal, Colter Barnes in the Southeast Island School District acts as a liaison between teachers and greenhouses to develop lessons, curriculum, and resources to make it as easy as possible for teachers. "We are recruiting teachers that want to do this. Just like if you had an automotive program or a small engines program, you'd recruit people that had those skills, interest, and knowledge – we're doing the same thing with agriculture."



In Tok, the main goal of the greenhouse is the production of fresh produce for school district cafeterias. Tok School is integrating the greenhouse into lesson plans as well. They offer tours to students from other schools in the district, combined with a nutrition lesson from a University of Alaska Fairbanks Cooperative Extension Service agent. In Fall 2016, teachers incorporated the greenhouse into two classes. An elective gardening class meets in the greenhouse for one hour each morning Monday – Thursday to help the greenhouse manager with daily tasks and talk about the bigger picture of food production. As the year progresses, the students learn to observe the plants and brainstorm daily tasks themselves, instead of simply being given a list of chores to do. The students meet in a classroom on Fridays to work through an agriculture curriculum from the company Odysseyware. The second class, an elective class on culinary arts, uses the greenhouse to grow herbs to use in their cooking. Bonnie Emery, the greenhouse manager, counts working with students in a gardening class and leading tours and field trips as one of her favorite parts of her job. As she puts it, "One of the best parts of the job is getting kids access to fresh vegetables...and watching them get to pull a carrot out of the ground for the first time." The district's superintendent echoes that sentiment, "My favorite part is seeing the change in kids' attitudes towards fresh foods. Teaching them to like fresh food, where it comes from, getting them used to it. It's part of the [the district's] whole focus on living a healthy lifestyle."

K-12 education

Biomass-heated greenhouses offer a rich teaching environment for schools. They can not only provide fresh produce for school lunches, but also a venue for scientific experiments, clubs, or work skill development. Some schools use student employees to operate the heating appliance and grow produce in the greenhouse.

All education programs should seek to engage students without making them feel overworked. The goal is to maintain teacher and student excitement about the project over time. For instance, allow students to work on different parts of the project to continually learn new skills; train students and staff to serve in leadership positions; provide employees and students benefits such as fresh produce for their families; use the greenhouse for a self-designed experiment, or a paycheck; and find a method for all involved to give feedback about what parts of the education are working and what parts might need revision.

Advertise the project throughout the school so staff, teachers, and students are aware of the project and its benefits. If produce is being served in the cafeteria, make posters to inform students where their food came from. Recognize students and staff who contributed to the greenhouse or biomass appliance at school gatherings so their peers know whom they can ask about how to get involved.

Finally, build an educational program into multiple classes, electives, and clubs over time. If one teacher leaves or retires, others can carry on the educational program.

8 LEARNING
EDUCATION FOR STUDENTS, STAFF & THE COMMUNITY

Some ways to use a biomass-heated greenhouse project at a school include:

Integration into core subjects such as math, science, art, and writing: Biomass-heated greenhouses can serve as laboratories for science classes as well as art and writing classes. The space could be used sporadically or integrated into a semester-long project. Create a method for teachers to coordinate with other staff and to allocate space and time to each subject. This might be a monthly meeting, a staff member in charge of scheduling, or an online calendar.

Integrating a new resource into lesson plans and standards takes time. There are several resources for existing curriculum that can be adapted (see end of this chapter for a list). Training is important both to provide teachers with general knowledge relating to the project and skills such as how to safely teach in those environments. There are many ideas for stand-alone activities and longer projects in core subject classes–use the following list as a starting point.

- **Math:** Calculate the fraction of moisture in cordwood | Calculate the number of plants that can fit into a raised bed.
- **Chemistry:** Learn which combustion gases are produced when biomass burns | Measure the pH of water in a hydroponics system.
- **Biology:** Calculate the volume of wood burned in a year. How would this be different if your school was located in a different area of Alaska? | Set up multiple plants in the same growing system, but vary the fertilizer components for each one. As the plants grow, have students determine which visual characteristics are associated with which nutrient deficiency.
- **English:** Practice science writing skills by describing how biomass fits into the carbon cycle | Use the greenhouse space in the winter for writing inspiration.
- **History:** Research how Alaskans traditionally heated their homes | Dedicate a section of a greenhouse to growing plants native to Alaska.
- **Communications:** Train students to lead tours in the biomass-heated greenhouse so they can practice communication skills.

Integration into elective classes: Elective classes can utilize biomass-heated greenhouses to complement their existing curriculum, or schools can build electives around the project. For instance, a school may have students in an existing construction course help with the design and building of a greenhouse. Or, a school may create a new course on management designed to operate the biomass appliance and greenhouse. Some other ideas follow.

- **Accounting:** Students are in charge of tracking costs, sales, and profit from a greenhouse.
- **Business:** Students conduct marketing surveys in the community.
- **Journalism:** Students create a video documentary about a project.
- **Language and culture:** Students learn new vocabulary by planting, cooking, and eating produce from a particular culture or region.
- **Culinary arts:** Students grow ingredients for a selected recipe.

After school clubs: These are a great way to combine K-12 education with community education. Meeting times can be during lunch, after school, or on weekends, allowing community members to attend or volunteer while maximizing student involvement. Clubs may be a local chapter of a national organization such as the National FFA Organization, SkillsUSA, or 4-H. These organizations provide state and national conferences and competitions that can help motivate students.

At Palmer High School, Don Berberich teaches a "Greenhouse Production" class each year. The class is modeled after a business, with Mr. Berberich as the "owner." He interviews students and hires four students as managers of different departments (Flower, Vegetable, Logistics, Custodial). The student managers, with guidance from Mr. Berberich, then are in charge of "hiring" employees, what to plant and how much, as well as selling their produce at the end of the semester. Photo courtesy Palmer High School.

Community education

Community education might consist of classes or volunteering opportunities where community members gain skills in enterprise, energy, and agriculture. It can fill any niche that a community needs, so ask community members for their ideas.

Classes/workshops: Classes can be held on weekends or evenings, or even during the week if the biomass-heated greenhouse is not being used for other purposes. Having a local project site lets students see an entrepreneurial project firsthand and learn. A great place to begin setting up workshops is the University of Alaska Fairbanks Cooperative Extension Service webpage. There are handouts and publications on a number of topics related to agriculture and energy that can serve as a basis for teaching a class. Cooperative Extension Service staff can also point teachers towards funding and other resources for classes.

Volunteer opportunities: Community members might be your most enthusiastic volunteers as biomass-heated greenhouse projects give them an opportunity to contribute in a way that benefits the community. They also can fill important gaps in a project's workload–such as firing a biomass-appliance on the weekends or monitoring crops during the summer when school is out. However, it is important to have a plan for handling volunteers and to specify guidelines in the implementation plan. For instance, what initial training should be involved? Do they need to sign a waiver? How will their hours be documented? And will they be compensated–not monetarily, but in produce, documented hours, or a reference letter?

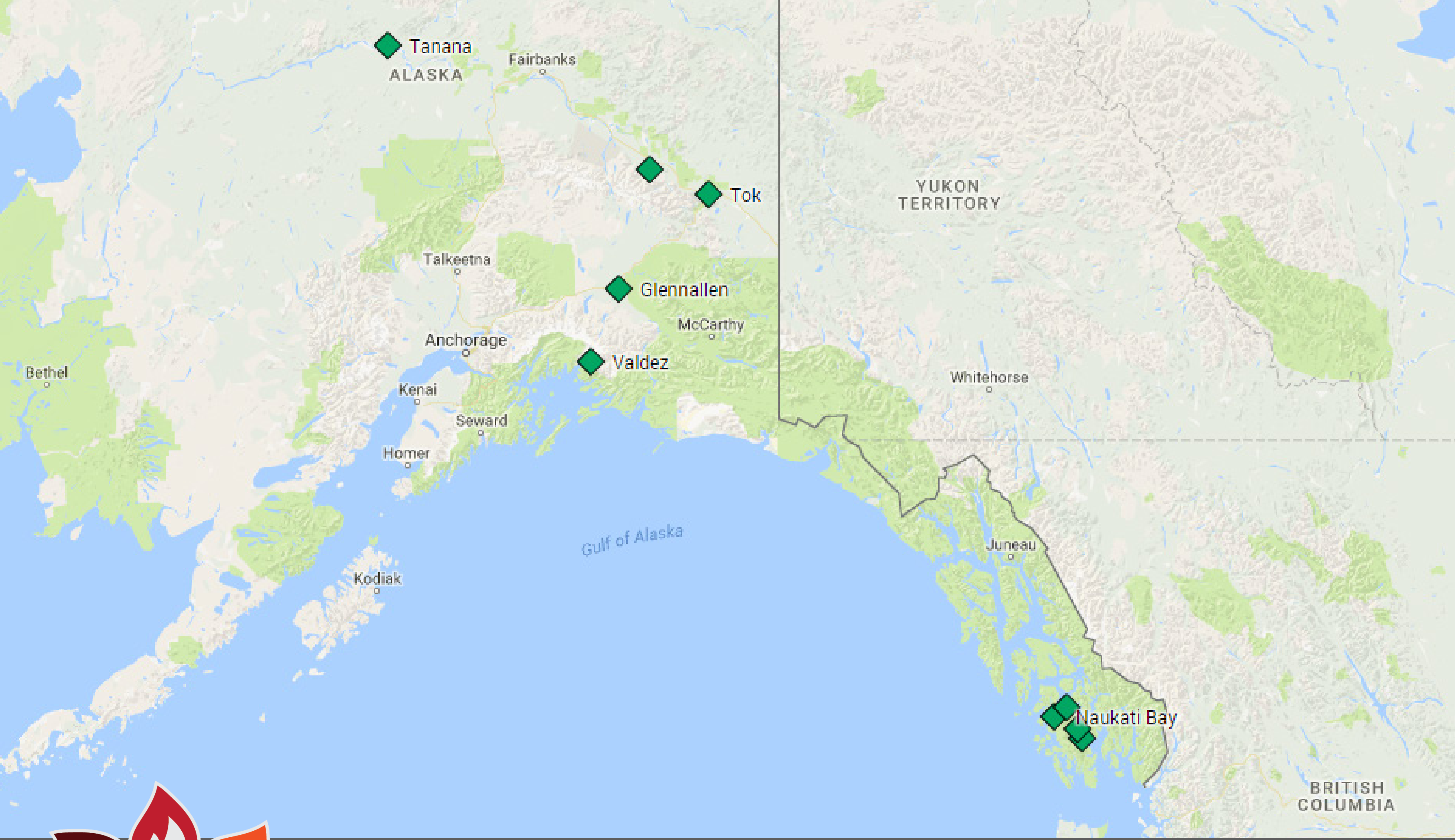
In Glennallen, the Copper Valley Development Association used a USDA grant to hold weekend classes at their biomass-heated containerized growing unit. The classes were aimed at adults and small businesses interested in implementing a similar project.

Photo courtesy Copper Valley Development Association.

"Within the school itself, seeing kids recognize the healthy benefits of eating fruits and vegetables and recognizing that they can do this at home, that this is a life skill that they can carry on through their adult life. That to me is the most rewarding, they want to make their own systems and bring them home. They bring their families in and give them little tours of the greenhouse. The engagement between the school, the families and the community it just provides a fantastic platform for engaging all those people."

- Megan Fitzpatrick, Teacher, Southeast Island School District

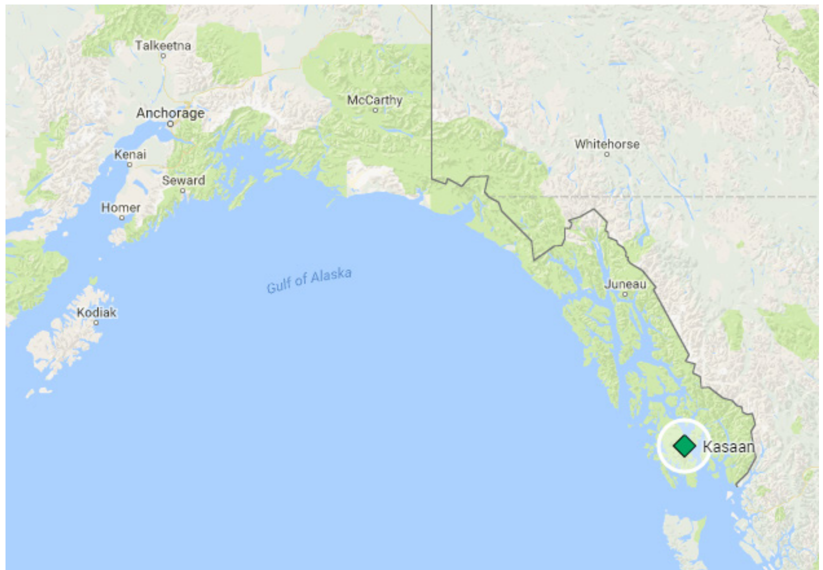
Curriculum Resources The following ideas are a great starting point to develop a curriculum that fits with a project's goals and resources.	**Alaska or Common Core Standards**	**Age**	**Sample lesson plan**
Alaska Farm to School Program: Alaska Division of Agriculture operates this program to increase the availability in schools of products produced and/or harvested in Alaska. The program offers many resources for educators, including student activities and safety workshops.	No		Carrot Seed Tape Activity
Alaska Master Gardener Blog: This website is maintained by the University of Alaska Fairbanks Cooperative Extension Service and features blog entries from students in Master Gardener courses. Many of the students are K-12 teachers who contribute lesson plans on agriculture for their posts (see the category "Gardening with kids").	Yes (AK)	K-12	Pollinators in Alaska
Biomass Energy Student Handbook and Activity Book: This NREL publication introduces energy in general before addressing specific information about biomass. It contains three activities for learning about energy.	No	9-12	Producing Energy from Biomass
Center for Ecoliteracy Resources for Educators: This website contains resources, activities, lesson plans and discussion guides that focus on the interdependencies between people and the environment and sustainable living.	Yes (CC)	3-12	The Tomato Salsa Challenge
Curriculum for Agricultural Science Education (CASE): This curriculum is a for-purchase learning management system that contains activities, projects, and problems for agricultural education. Curriculum categories include plant science, agricultural engineering, agricultural business, and natural resources. CASE also offers professional development courses for teachers.	Yes (CC)	9-12	Influence of Nutrients in Food
Education OUTSIDE: This organization promotes the use of the outdoors in science and environmental education. They have resources for school gardens, including curriculum and a guide to starting a school garden on their website.	No	K-5	
Fairbanks Soil & Water Conservation District: This organization contains a wide variety of conservation education resources to help everyone from formal school educators to informal after-school groups. The overall goal is to help students appreciate natural resources and use them wisely. Programs include Wet Education for Teachers, Project Learning Tree, Project WILD, Ag in the Classroom, early education, and composting workshops. Kits and resources are available for loan.	Yes (AK)	K-12	Is a muskox an ox?
Junior Master Gardener: This certification program for students promotes a love of gardening and the environment as well as building leadership and service skills. The website has curriculum and teacher training courses for purchase.	No	1-8	Literature in the Garden
Mobile Greenhouse Teacher Guide & Student Activities: Grow Southeast, the Sustainable Southeast Partnership, and HAA AANI collaborated on a mobile greenhouse that travels the Southeast region of Alaska to help communities strengthen food systems. The teacher guide contains resources such as water record-keeping tables, maintenance checklists, and curriculum.	No	K-12	How to Read a Seed Packet
Nelson and Pade, Inc. Hydroponics Curriculum: This for-purchase curriculum package contains videos, student manuals, and educator guides for facilitating hands-on learning in plant science, plan nutrition, plant care, and other agriculture subjects.	No	7-10	
Odysseyware: This for-purchase curriculum offers online, customizable instruction in a variety of topics, including Agriculture, Food, Natural Resources, Plant Systems, and Agribusiness.	Yes (CC)	K-12	
Raising Educational Achievement through Cultural Heritage (REACH): This program aims to increase student achievement in STEM subjects and prepare youth to find solutions to local climate change issues. Lesson topics include heat, water, weather, measurements, Earth, seasons, food, and temperature.	Yes (AK)	K-6	What are some plants in your area and how are they used?
Science Activities in Biomass: This NREL publication contains activities that address biomass from both plant growth and energy perspectives.	No	4-6	How much biomass is produced by 1 square meter of a local weed?
Team Nutrition: This USDA initiative promotes healthy eating and physical activity through training and technical assistance for teachers, nutrition education for children, and support for schools and communities.	No	Preschool - 12	The Importance of Eating Breakfast
University of South Florida Wood Energy High School Education Program: This program contains teacher resources, activities, and supplemental reading and presentations. The comprehensive unit follows the overall theme of answering "Should our community use biomass for energy?" While content is specific to the Southeastern United States, many of the activities can be translated to any community.	No	10-12	Biomass Perspectives



APPENDIX

CASE STUDIES FROM ALASKAN COMMUNITIES

APPENDIX
CASE STUDY:
BARRY C STEWARD KASAAN SCHOOL, SOUTHEAST ISLAND SCHOOL DISTRICT (SISD)



Start: 2015

Goals: The Southeast Island School District (SISD) initially started the greenhouse program, now at four schools, to improve the school lunch program. Students were eating canned vegetables that had been reheated in school kitchens; now school cafeterias feature salad bars with fresh greens. The greenhouse also provides hands-on education and opportunities for students to learn job skills that will serve them long after graduation. The program has also strengthened the connection between the schools and the community, and the biomass boilers take advantage of a stable, low-cost energy source.

Management: Management of the biomass boilers and greenhouses is continually changing as district employees gain more experience learn what works at each school. Currently, the district's wood-fired boiler project manager provides overall management for all biomass boilers in the school district and one of the school principals oversees and provides direction for greenhouse operations. District employees from all four schools with greenhouses meet once a month to share successes and challenges.

At Barry C. Steward Kasaan School, teachers manage day-to-day operations for the biomass boilers, which heat the school, teacher housing, and greenhouse. Teachers receive a discount on heat for their homes in return for running the boiler operations. The lead teacher at the school is also the on-site greenhouse manager. Students are responsible for day-to-day tasks such as loading and operating the boiler and plant care.

Building: The greenhouse is 864 square feet, 24 feet wide by 36 feet long. It was built from a Gothic Arch kit that consists of a wood frame and double polycarbonate panels built on a cement foundation. The cost of the kit was $17,550. It was shipped with the kit for the greenhouse in Naukati School for a total of $4,455.

Heating: A GARN 2200 (from Alaska Heat Technologies) cordwood boiler provides heat for the school and greenhouse. The boilers, which cost approximately $17,000 each, provide heat to the water in the aquaponics system and forced-air unit heaters. The anticipated fuel usage is 60 cords of wood per year.

Growing: The greenhouse employs an aquaponics system to grow produce. The district chose aquaponics due to the limited availability of soil in Southeast Alaska. Kasaan School also has raised beds outside the greenhouse and students constantly add nutrients such as seaweed to build the soil and counteract heavy rainfall. All of the SISD greenhouses grow lettuce, which is sold to the school cafeterias for their salad bars. It is also sold to the school district's cafe in Thorne Bay and local grocery stores. Other vegetables are rotated in and out, with varieties dependent on student and teacher choice and curriculum. In the past, they have grown kale, basil, and chard, as well as carrots, turnips, and radishes.

Teaching: SISD started the school greenhouses in 2014, so teachers are still figuring out how to integrate them into courses. Overall direction for the educational aspect is provided by Colter Barnes, principal at Howard Valentine School in Coffman Cove. At smaller schools such as Kasaan, students from all grades visit the greenhouse in a group to learn as they perform day-to-day tasks or participate in a planned activity. Mr. Barnes estimates he and the school district staff make 80% of their curriculum on site because of the unique system, "biomass-heated aquaponics is fairly rare."

Funding: The greenhouses and heating systems were funded by a combination of grants, legislative funds, and in-kind donations from the district. For ongoing operations, profit from vegetable sales goes back into the greenhouse fund at each school. The district has also applied for and received grants to supplement vegetable sales in the past, such as Alaska Nutritional Foods grants and small foundation grants. District funds make up the remaining operations funding.

C-GRO UNIT, COPPER VALLEY DEVELOPMENT ASSOCIATION (CVDA)

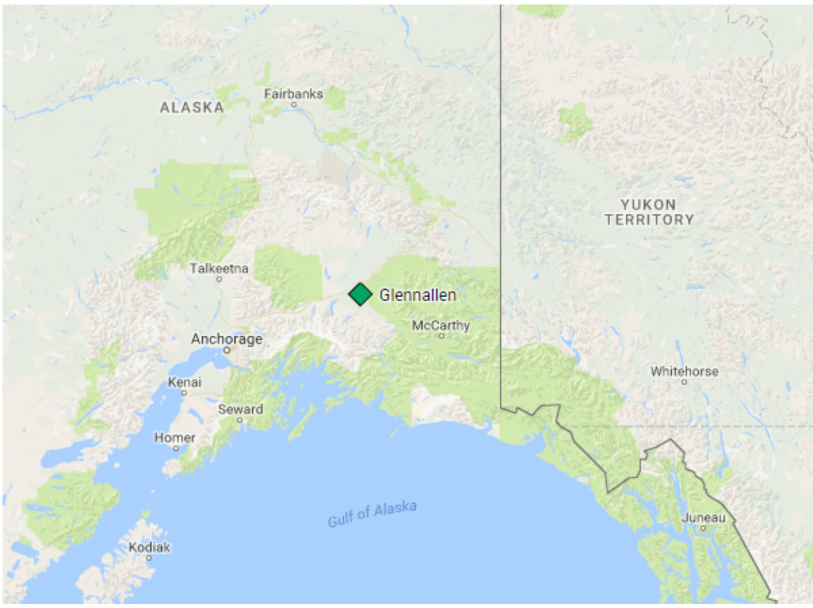


Photo courtesy Copper Valley Development Association.

Start: The C-GRO unit was built in 2013. It originally was located at Glennallen School. However, the school district was unable to maintain it so it was sold to a Copper Valley farmer who is currently using the unit to produce and sell vegetables.

Goals: The primary goal of the unit was to produce healthy vegetables for the school and community. The secondary goal was that the vegetable sales produce enough profit to fund the C-GRO's operation.

Management: The CVDA and the Career and Technical Education (CTE) teacher at Glennallen School jointly managed The C-GRO unit. The CTE teacher ran the school's Skills USA club, a chapter of the national vocational program. The club met after school to manage the greenhouse: firing the boiler, checking the hydroponics system, and harvesting and packaging plants.

Building: The C-GRO unit is built into a shipping container. It is both self-contained and mobile. It contains heating, ventilation, and hydroponics systems. There is both space for growing plants and a workspace for preparation and processing.

Heating: The unit is heated by a Profab 1500 cordwood boiler and burns approximately 5-6 cords of wood per year. In the Copper Valley, a cord of wood is approximately $200, so the annual heating cost came to approximately $1,200. The boiler has its own holding tank of water. Typically, the CTE teacher would fire the boiler during weekday mornings, and the Skills USA club would fire it again in the weekday evenings. On the weekends, typically students were paid $20/hour to fire the boiler. If no students were available, the teacher would fire the boiler.

Growing: The unit contains a completely automated hydroponics system. Plants are grown in rock wool cubes. The system uses approximately 150 gallons of water, which is kept in storage tanks and changed every 3-4 weeks. Electric use for the unit is approximately 30-40 kWh/day, depending on the use. In Glennallen, electricity is approximately $0.38/kWh, so the monthly electrical cost was around $400. Students have grown lettuce, cabbage, spinach, kale, celery, basil, cilantro, and parsley. The unit contains space for processing, and students washed and packaged the vegetables on-site.

Teaching: The Skills USA club at Glennallen School, run by the CTE teacher, was responsible for daily operation. This allowed the students in the club to develop agricultural, operation and management, and business skills. The school used the hydroponics curriculum package from Nelson and Pade, Inc. to teach agriculture topics such as plant science, nutrient and pH testing, and plant nutrition. In addition, weekend classes for community members were held in the unit on topics to help others implement similar projects. The unit also had a distance education video stream so that attendees of distant conferences on horticulture in Alaska could see its operation live.

Funding: The CVDA received a small grant from the Alaska State Legislature to study a controlled greenhouse environment. They decided the best study would be to build a controlled greenhouse environment, and used the grant as capital funding to construct the C-GRO unit. A USDA grant covered weekend educational classes. Operational funding came from vegetable sales. For instance, heads of lettuce were sold wholesale to restaurants, schools, and grocery stores for $3 each. The general public paid $4/head of lettuce. As the unit could produce approximately 125 heads of lettuce each week, revenue came to $1,500 to $2,000 per month. This revenue paid for electricity and heating, as well as labor for operating the boiler, running the hydroponics system, and processing vegetables. Workers were paid $20/hour.

APPENDIX
CASE STUDY:
CORBIN CREEK FARM, VALDEZ, AK

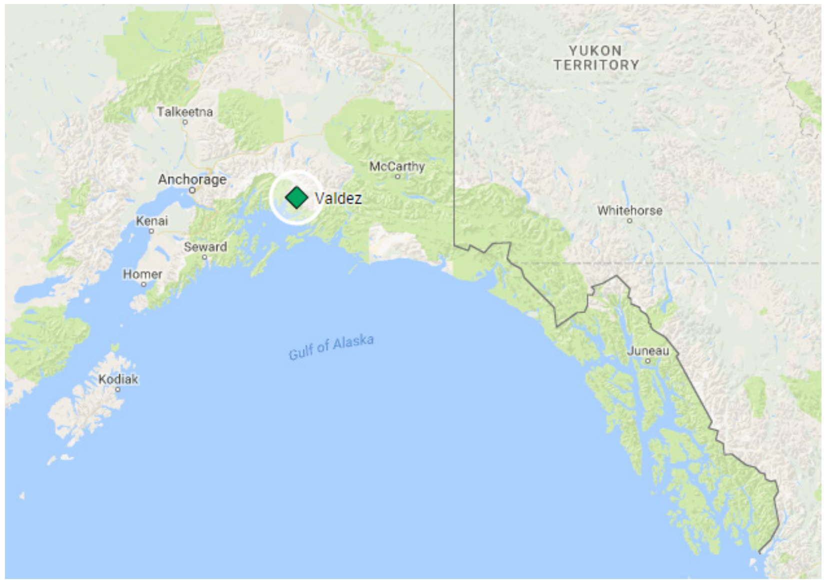
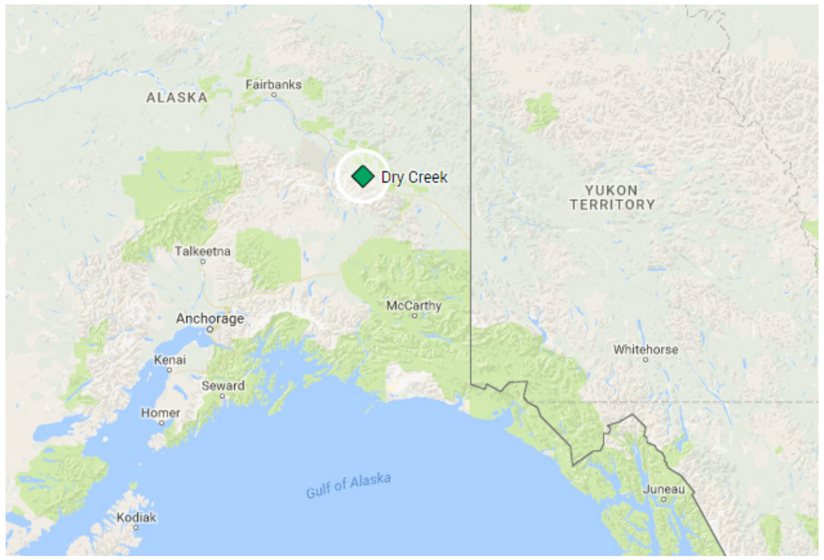
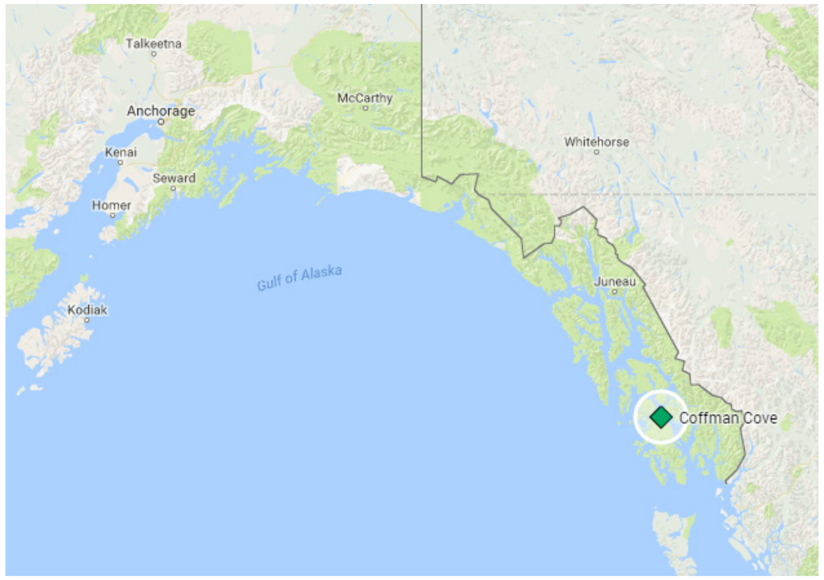


Photo courtesy Corbin Creek Farm.

Start: 2000
Goals: The primary goal of Corbin Creek Farms is to provide locally grown vegetables to the Valdez community. The farm sells vegetables through the local Farmer's Market and to restaurants around town. Mr. Engle views his farm as a continuous experiment, and is always looking to new technologies and techniques to maximize production. As he puts it, "The whole idea in the beginning was to grow produce in this kind of climate. As I progressed, more people started asking about it, so I started looking at it as a learning experiment."
Management: John Engle manages the farm, including several high tunnel greenhouses. He has been gardening for almost two decades in Valdez, and prior to moving there, farmed in Fairbanks for 30 years. Right now, it is just him working his farm, although eventually, he hopes to hire a summer hand.
Building: The farm has several high tunnel greenhouses of varying sizes. They are built from a variety of kits, to take advantage of the characteristics that do well in his location in coastal Alaska. For example, he uses gothic style roofs so that snow can slide off, and he modifies the kits to be shorter in height to lower the greenhouse profiles for the strong winds in Valdez. All of the greenhouses contain ventilation systems to ensure adequate airflow, because mold is prevalent in Valdez and Mr. Engle has found that the high humidity of the greenhouses forms ideal conditions for mold growth. He uses a combination of vents and high volume fans to pull air through the greenhouses. Valdez has hydroelectric power, so electricity is relatively cheap in the summer. None of the greenhouses has supplemental lighting.
Heating: One of the high tunnels contains a biomass heating system. It consists of a rocket mass stove, with exhaust vented through ducts underneath the ground to provide heat to the soil. This is an experimental system, and Mr. Engle uses that greenhouse to extend the growing season rather than to grow through the winter.
Growing: Plants grown in the high tunnels grow in pots or directly in the ground. In the heated high tunnel, Mr. Engle runs a succession planting plan. In the spring, he plants crops that like cooler soil, such as carrots, radishes, and lettuce. After harvesting those, the greenhouse is used for warmer season crops like beans, for the summer. In the fall, he rotates back to the cooler season crops to get one more harvest before winter. He has found that Tuscan kale and chives can handle the cold temperatures and make it through the fall. He also grows crops outdoors once the soil temperature has warmed to 40 F in the spring. Typical outdoor crops include lettuce, carrots, and radishes.
Teaching: Mr. Engle gives presentations to the local garden club and the University of Alaska Fairbanks Cooperative Extension Service. He also hosts tours and answers questions from individuals in the community that have their own horticulture projects.
Funding: Mr. Engle provided the funding for his farm himself, through savings and agricultural loan programs. Operational funding comes from vegetable sales to the Valdez community. He sells vegetables at a market at his farm, the Valdez farmer's market, and a few restaurants around Valdez. He tries to keep prices realistic: he needs to pay for operational funding for his farm but doesn't want people to feel he is charging too much. He has yet to make a profit, and is focused on educating buyers on how he develops his pricing, developing a good reputation, and remaining consistent year-to-year.

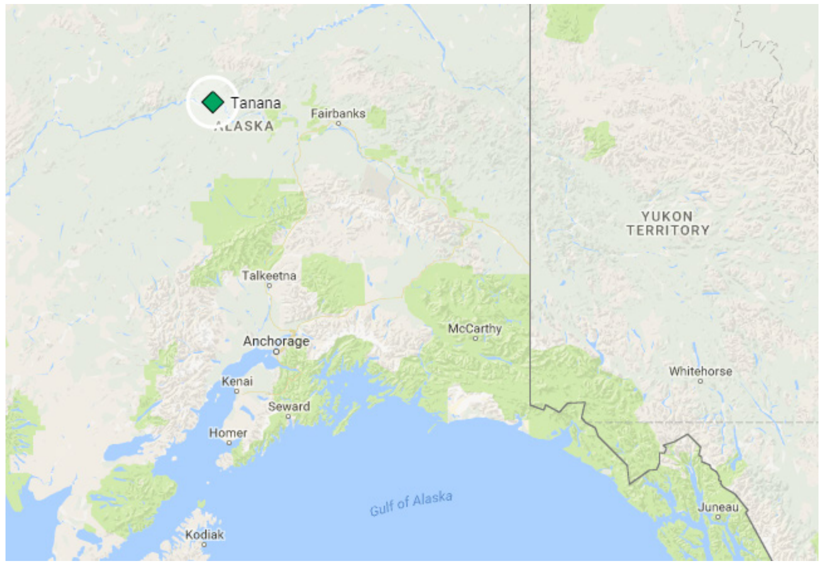


Start: Dry Creek Community was founded in 1973. The community has always employed greenhouses for growing produce, although the style and management has varied over the years. Currently, the community has two biomass-heated greenhouses.
Goals: The primary goal of the greenhouses in Dry Creek is to provide produce for the community. Fresh vegetables go to the cafeteria for community meals and are also canned and frozen for winter meals. The greenhouse also allows community members to see where their food comes from, and serves an educational purpose. Youth and other community members work in the greenhouse to learn agriculture and production skills.
Management: The greenhouses are managed and staffed by community members.
Building: The community operates two biomass-heated greenhouses. Both are constructed from Agrotech kits. They have a metal frame and double polycarbonate walls. They do not contain supplemental lighting. For cooling, vents on top and sides of the greenhouse open. Staff also will employ a hand mister on very hot days.
Heating: Cordwood boilers provide heat to the greenhouses. Community members run the boilers. There is also a back-up propane heating system, for times when the cordwood boilers require maintenance or if they are not stoked on time. The back-up system is critical in the spring, because they do not want to lose their starter plants in case the boiler isn't operating. Heat is distributed via fin tubes under the benches. The floor is not heated or insulated: that would help to retain heat, but they feel it is more important to be able to cool the greenhouse quickly on hot days.
Growing: The community uses the greenhouses for starting plants in the spring and for growing vegetables that require additional heat throughout the summer. Plants are grown in pots on benches in the greenhouses. The total greenhouse season runs from late March through September. In the winter the greenhouse freezes.
In the spring, all the plants are started in the greenhouse; then, as the starters are transplanted outside, the summer greenhouse plants are able to expand to larger pots. Summer vegetables include tomatoes, bell peppers, cucumbers, and hot peppers. The timing works out so that just as the summer vegetables have grown enough to require more space in the greenhouse, the starter plants move outside into the ground.
Funding: Dry Creek Community funded the greenhouses. In the past, the community sold produce to restaurants in Delta Junction and maintained a total of four greenhouses to ensure a steady output. However, they currently are only staffing two greenhouses to provide produce to the community.



Start: 2016
Goals: SISD initially started the greenhouse program, now at four schools, to improve the school lunch program and provide better nutrition to the students. Students were eating canned vegetables that had been reheated in school kitchens; now school cafeterias feature salad bars with fresh greens. The greenhouse is also for hands-on education, and provides opportunities for students to learn job skills that will serve them long after graduation. Other benefits have included increasing the connection between the schools and the community, and, from the biomass boilers, having a stable, low-cost energy source.
Management: The management of the biomass boilers and greenhouses is continually changing as the district employees gain more experience with the projects and learn what works at each school. Currently, the district wood-fired boiler project manager provides overall management for the biomass boilers in the school district and one of the school principals oversees and provides direction for greenhouse operations. District employees from all 4 schools in the district with greenhouses also meet once a month to share what is working, troubleshoot what is not working, and plan future changes.
At Howard Valentine Coffman Cove School, student employees manage the day-to-day operations for the biomass boilers, which heat the school and greenhouse. The lead teacher at the school is the on-site greenhouse manager.
Building: The greenhouse is a 7,000-square-foot steel-frame built on a cement foundation. The glazing is a mix of tempered glass and double polycarbonate panels. This greenhouse kit came from a nursery in the lower 48 that purchased the kit with the intention of using it themselves. However, they did not need it and sold it as-is to the school district for a discounted price.
Heating: A GARN 2200 (from Alaska Heat Technologies) cordwood boiler provides heat for the school and greenhouse. The boiler provides heat to the water in the aquaponics system. The water in the aquaponics system, heated to 80 F, keeps the air in the greenhouse warm as well. The cost of the boiler was approximately $17,000.
Growing: The greenhouse employs an aquaponics system to grow produce. The district chose aquaponics due to the limited availability of soil in Southeast Alaska. Dirt is virtually unavailable. Howard Valentine School also has raised beds outside of the greenhouse, and students are constantly adding nutrients such as seaweed to build the soil and counteract the heavy amount of rainfall. All of the SISD greenhouses grow lettuce, which is sold to the school cafeterias for their salad bars. It is also sold to the school district's cafe in Thorne Bay and local grocery stores. Other vegetables are rotated in and out, with varieties dependent on student and teacher choice and curriculum. In the past, they have grown other greens such as kale, basil, and chard, and root vegetables including carrots, turnips, and radishes.
Teaching: SISD has operated greenhouses at schools since 2014, so the integration of the greenhouse into courses is still evolving as teachers continue to find methods to incorporate it into the curriculum in ways that work for them. Overall direction for integrating the greenhouse into education is provided by Colter Barnes, the school's principal. At smaller schools in the district, such as in Coffman Cove, typically students from all grades visit the greenhouse in a group to learn as they perform day-to-day tasks or participate in a planned activity. Mr. Barnes estimates that he and the school district staff make 80% of their curriculum on site because of the unique system, "biomass-heated aquaponics is fairly rare."
Funding: Capital cost for the heating systems and greenhouses in the district has come from a combination of grants, legislative funds, and in-kind donations from the district. For ongoing operations, profit from vegetable sales goes back into the greenhouse fund at each school. The district has also applied for and received grants to supplement the vegetable sales in the past, such as Alaska Nutritional Foods grants and small foundation grants. District funds make up the remaining operations funding.

MAUDREY J SOMMER SCHOOL, TANANA CITY SCHOOL DISTRICT



Start: 2016

Goals: The main goal of the biomass-heated greenhouse is for it to serve as an educational living laboratory. It will also allow students to grow their own food for school lunches. The larger, long-term vision is that the greenhouse can provide jobs in the community, provide fresh, affordable vegetables to the region, and provide incentives for living in the community.

Management: The superintendent and principal of the school in Tanana oversee the project with input from the City of Tanana and the Tribal Council. A consultant, Devta Khalsa, serves as the project champion, advising the school district on next steps and keeping the momentum going forward. Finally, a local teacher with gardening experience is the on-site coordinator for day-to-day operations.

Building: The greenhouse shell was constructed in Fall 2016. It is 30 feet by 60 feet, and is built from a kit from Stuppy, Inc. The kit cost was $89,000, including shipping, and it was delivered in a shipping container by a barge. The building has a concrete floor and steel framing. The North wall does not have glazing; the other walls feature a 2-feet tall pony wall and twin polycarbonate panels above that. The reason the North wall does not have glazing is because the prevailing wind in Tanana comes from the North, and there is not much light gain from that direction. The design also calls for the GARN boiler, restroom, entry, storage, and a veggie washing station to be located along the North wall. The greenhouse will have automated ventilation, watering, and lighting. The control system will connect to a phone app to let a caretaker know when something isn't working.

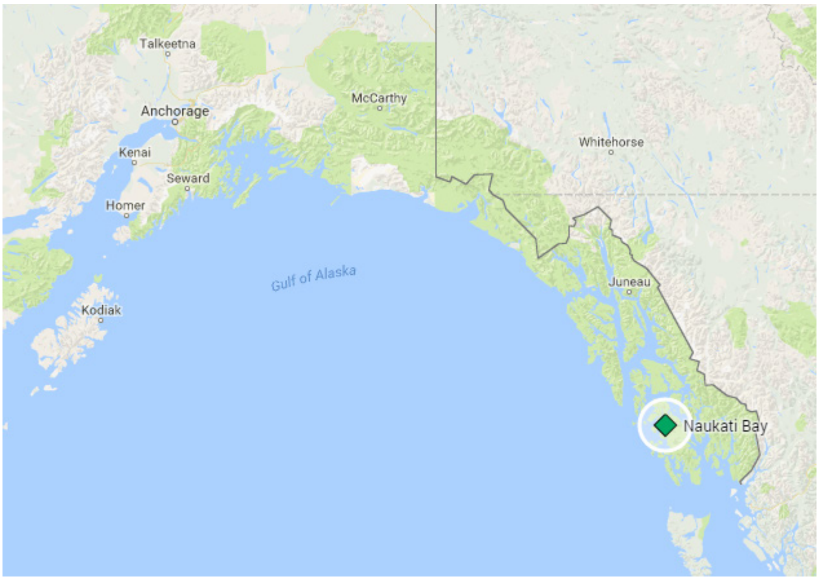
Tanana hired one person with greenhouse construction experience to read the kit instructions and construction plans, and serve as foreman. The remaining construction crew was made up of Tanana residents. None had previous experience with greenhouse kits. It took the 5-person crew approximately 4 weeks to complete the construction, which went smoothly.

Heat: A cordwood GARN boiler will provide heat to the greenhouse via a radiant floor and forced air blowers. The greenhouse will have different zones to allow the air temperature to be tailored to the individual crops in each area. There will be a Toyo stove for back-up heat when the boiler needs maintenance or for times when school employees are not available to run the boiler.

Growing: The school plans to have raised beds for growing vegetables. They also plan to have a hydroponics system and outside beds in the future.

Teaching: The greenhouse is already being integrated into the curriculum as students are documenting the building through pictures, video, and text to be used in a future manual of operations and documentary film. Students are also focused on learning plant biology, horticulture, soil building and microbes, and the principles of Permaculture so that they will be ready for planting when the time comes. The greenhouse consultant, Devta Khalsa, feels that it is important to really submerge the biomass-heated greenhouse project into the school, and provide resources to teachers for aligning curriculum. This strategy will help to ensure the longevity of the project. Thus far, Ms. Khalsa has not relied on any particular packaged curriculum. Instead, she has made curriculum based on her own experience and in response to the needs of the students.

Funding: The city and Tribal Council co-owned the cordwood boiler at the project start. Remaining capital funding came from district funds that were leftover from a project to repair the gymnasium roof and donations of building supplies, including the cement for the floor and plywood for the walls. They have applied for grant funding to get the greenhouse operations up and running. The next phase of the project will be to build support buildings and purchase garden supplies. The project team is continually refining their funding strategy as the project progresses.



Start: 2015
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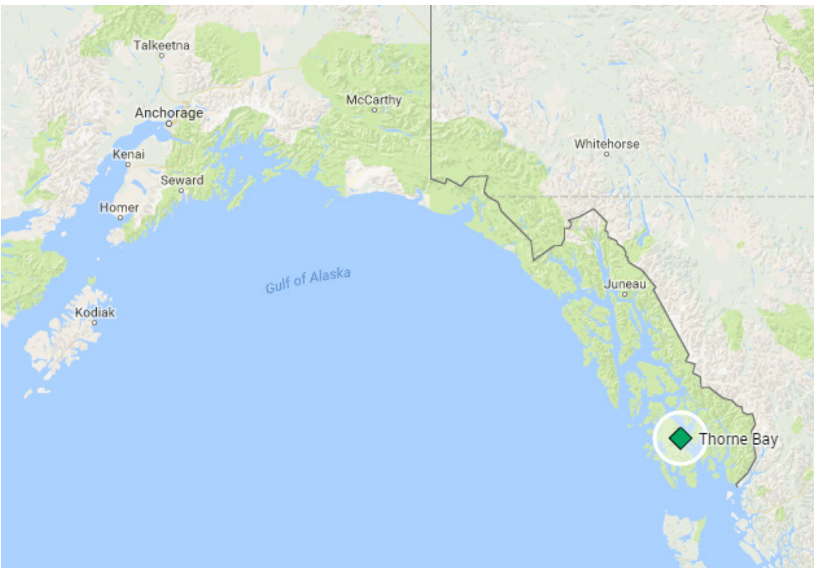
Management: The management of the biomass boilers and greenhouses is continually changing as the district employees gain more experience with the projects and learn what works at each school. Currently, the district wood-fired boiler project manager provides overall management for the biomass boilers in the school district and one of the school principals oversees and provides direction for greenhouse operations. District employees from all 4 schools in the district with greenhouses also meet once a month to share what is working, troubleshoot what is not working, and plan future changes.
At Naukati School, student employees manage the day-to-day operations for the biomass boilers, which heat the school and greenhouse. The lead teacher at the school is the on-site greenhouse manager.
Building: The greenhouse is 864 square feet, 24 feet wide by 36 feet long. It was built from a Gothic Arch kit that consists of a wood frame and double polycarbonate panels built on a cement foundation. The cost of the kit was $17,550. It was shipped with the kit for the greenhouse in Naukati School for a total of $4,455.
Heating: A GARN 2200 (from Alaska Heat Technologies) cordwood boiler provides heat for the school and greenhouse. The boiler provides heat to the water in the aquaponics system and forced-air unit heaters. The anticipated fuel usage is 60 cords of wood per year. The cost of the boiler was approximately $17,000.
Growing: The greenhouse employs an aquaponics system to grow produce. The district chose aquaponics due to the limited availability of soil in Southeast Alaska. All of the SISD greenhouses grow lettuce, which is sold to the school cafeterias for their salad bars. It is also sold to the school district's cafe in Thorne Bay and local grocery stores. Other vegetables are rotated in and out, with varieties dependent on student and teacher choice and curriculum. In the past, they have grown other greens such as kale, basil, and chard, and root vegetables including carrots, turnips, and radishes.
Teaching: SISD has operated greenhouses at schools since 2014, so the integration of the greenhouse into courses is still evolving as teachers continue to find methods to incorporate it into curriculum in ways that work for them. Overall direction for integrating the greenhouse into education is provided by Colter Barnes, the principal at Howard Valentine School in Coffman Cove. At smaller schools in the district, such as in Naukati, typically students from all grades visit the greenhouse in a group to learn as they perform day-to-day tasks or participate in a planned activity. Mr. Barnes estimates that he and the school district staff make 80% of their curriculum on site because of the unique system, "biomass-heated aquaponics is fairly rare."
Funding: Capital cost for the heating systems and greenhouses in the district has come from a combination of grants, legislative funds, and in-kind donations from the district. For ongoing operations, profit from vegetable sales goes back into the greenhouse fund at each school. The district has also applied for and received grants to supplement the vegetable sales in the past, such as Alaska Nutritional Foods grants and small foundation grants. District funds make up the remaining operations funding.

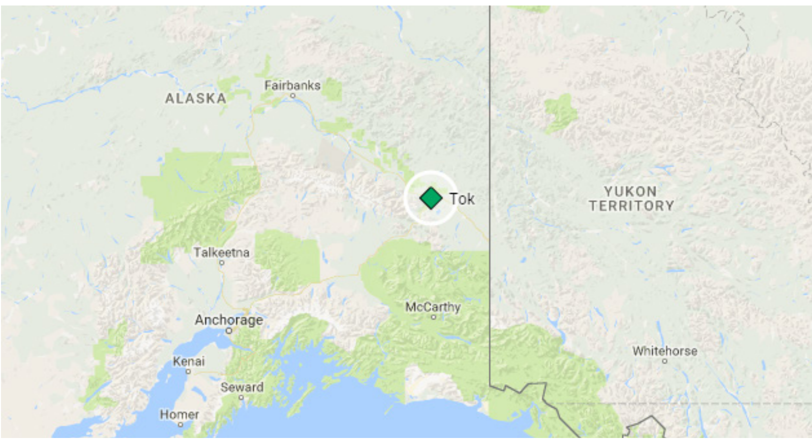
APPENDIX

CASE STUDY:
THORNE BAY SCHOOL, SOUTHEAST ISLAND SCHOOL DISTRICT (SISD)



Start: 2014
Goals: SISD initially started the greenhouse program, now at four schools, to improve the school lunch program and provide better nutrition to the students. Students were eating canned vegetables that had been reheated in school kitchens; now school cafeterias feature salad bars with fresh greens. The greenhouse is also for hands-on education, and provides opportunities for students to learn job skills that will serve them long after graduation. Other benefits have included increasing the connection between the schools and the community, and, from the biomass boilers, having a stable, low-cost energy source.
Management: The management of the biomass boilers and greenhouses is continually changing as the district employees gain more experience with the projects and learn what works and doesn't at each school. Currently, the wood-fired boiler/biomass project manager provides overall management for the biomass boilers in the school district and one of the school principals oversees and provides direction for greenhouse operations. District employees with greenhouses also meet once a month to share what is working, troubleshoot what is not working, and plan future changes.
At Thorne Bay School, student employees manage the day-to-day operations for the biomass boilers, which heat the school and greenhouse. A science teacher at the school is the on-site greenhouse manager.
Building: The greenhouse is 792 square feet, 18 feet wide by 44 feet long. It was built from a Gothic Arch kit that consists of a wood frame and double polycarbonate panels built on a cement foundation. The cost of the kit was $28,235 and shipping was $2,170.
Heating: Two GARN 3200 (from Alaska Heat Technologies) cordwood boilers provide heat for the school and greenhouse. The boiler provides heat to the water in the aquaponics system, forced-air unit heaters, and a radiant floor. The anticipated fuel usage is 160 cords of wood per year. This new system replaced smaller boilers in 2016 to better cover the heating needs of the school and greenhouse. In 2016, the school burned 72.5 cords of wood (the first half of the year was using the smaller boilers before they were replaced in the summer). The GARN 3200 boilers cost approximately $42,000 each. Shipping for both was $12,000. The total cost of installing the boilers came to $240,000. In addition to the boiler cost and shipping, this included engineering feels, labor, and plumbing equipment.
Growing: The greenhouse employs an aquaponic system to grow produce. The district chose aquaponics due to the limited availability of soil in Southeast Alaska. Dirt is virtually unavailable. Thorne Bay School also has raised beds outside of the greenhouse, and students are constantly adding nutrients such as seaweed to build the soil and counteract the heavy amount of rainfall. All of the SISD greenhouses grow lettuce, which is sold to the school cafeterias for their salad bars. It is also sold to the school district's cafe in Thorne Bay and local grocery stores. Other vegetables are rotated in and out, with varieties dependent on student and teacher choice and curriculum. In the past, they have grown other greens such as kale, basil, and chard, and root vegetables including carrots, turnips, and radishes.
Teaching: SISD has operated greenhouses at schools since 2014, so the integration of the greenhouse into courses is still evolving as teachers continue to find methods to incorporate it into curriculum in ways that work for them. Overall direction for integrating the greenhouse into education is provided by Colter Barnes, the principal at Howard Valentine School in Coffman Cove. At smaller schools in the district, typically students from all grades visit the greenhouse in a group to learn as they perform day-to-day tasks or participate in a planned activity. Thorne Bay School is larger (current student population is more than 70) so the teachers schedule times and activities in the greenhouse by individual class or age group. Mr. Barnes estimates that he and the school district staff make 80% of their curriculum on site because of the unique system, "biomass-heated aquaponics is fairly rare."
Funding: Capital cost for the heating systems and greenhouses in the district has come from a combination of grants, legislative funds, and in-kind donations from the district. For ongoing operations, profit from vegetable sales goes back into the greenhouse fund at each school. The district has also applied for and received grants to supplement the vegetable sales in the past, such as Alaska Nutritional Foods grants and small foundation grants. District funds make up the remaining operations funding.

APPENDIX
CASE STUDY:
TOK SCHOOL, ALASKA GATEWAY SCHOOL DISTRICT



Start: The Alaska Gateway School District installed a boiler at Tok School in 2009. They constructed the greenhouse in 2012.
Goals: The primary goal of the greenhouse is to produce fresh vegetables in the cafeterias in the seven schools in the district. A secondary goal is to use the greenhouse to educate students in the district about where food comes from, and how to run a greenhouse.
Management: the school's biomass and agricultural manager oversee the greenhouse and biomass system. The district's greenhouse manager is in charge of daily operation and the Food Service Coordinator handles distribution of the vegetables to the individual schools.
Building: The greenhouse is a high tunnel with air-inflated double layer polyethylene sides. It was built from a kit from the Lower 48. It has no supplemental lighting, and plants grow in raised beds on the greenhouse floor. For ventilation, a controller rolls up the sides of the greenhouse and turn on fans when it is too hot. The greenhouse is located next to a separate building that contains storage space and a processing room with sinks and refrigerators for the vegetables.
Heating: A 5.5 MBTU wood chip boiler provides heat to Tok School, its sports complex, the greenhouse, and the greenhouse support building. The boiler also drives an electric generator in the winter and offsets about half of the school's electric use. Alaska Gateway School District gets their wood chips from a state fire mitigation and easement project. A staff member collects felled trees and stacks them into short piles to dry before they are chipped. They piles need to be shorter than 3 feet tall so the bottom trees do not rot. Each year, the district uses approximately 50 acres of felled trees for the boiler operation. The district's biomass and agricultural manager oversees the daily operation of the boiler, and is on-call at all times in case maintenance issues arise. However, the morning and night school janitors perform daily walkthroughs of the boiler building to ensure smooth operation. There is an oil-fired boiler back-up system for times when the biomass system requires maintenance. Heat is distributed through forced air fans hanging from the ceiling of the greenhouse, and through pipe buried in soil in some of the beds. The greenhouse manager makes sure that the plants that are grown in those beds are compatible with the higher soil temperature. The boiler also heats a tempering tank of water that is used to water plants.
Growing: Plants grow in raised beds and pots on the greenhouse floor. Growing is year-round, except for a break in January to let the greenhouse freeze for pest control. Crops consist of vegetables that can go directly into the school lunch program meals – lettuce, green beans, cucumbers, zucchini, and tomatoes. They also run small experiments with different vegetables to see how they could be incorporated into the existing lunch menu. The greenhouse manager waters plants by hand and also uses water lines and individual water timers on each bed to water. The water lines require maintenance: they have to be cleaned and if they are cut during harvest they need repaired. However, they allow the manager to take time off on the weekends! Currently, all nutrients are mixed by hand although in the future the greenhouse manager may look into automated mixing systems to save time. The greenhouse manager tests the soil by taking samples and sending it to the University of Alaska Cooperative Extension Service in Kenai. The soil testing results provide recommendations on which nutrients to add. In 2016, the greenhouse manager and the agricultural and biomass manager installed a heated compost pad outside of the greenhouse. Staff shred plant waste and put it into the compost pile. Eventually, they hope to also use food waste from Tok School's cafeteria as well and rely on only compost for fertilizer.
Teaching: The greenhouse is mainly used for commercial production for school cafeterias. However, students and community groups tour the greenhouse to learn about its operation and where vegetables come from. Also, in the 2016-2017 school year, Tok School implemented a greenhouse management class. Students work in the greenhouse four days a week, learning all aspects of plant management. On Fridays, the students complete Odysseyware distance education coursework on horticultural topics.
Funding: The school district received funding for the biomass boiler from the Alaska State Renewable Energy Fund. The district's match for the grant consisted of district general funds and a supply of biomass fuel for the first year of operation. The district paid for the greenhouse out of district general funds.

Interviewees

Many outstanding individuals contributed to production of this handbook, sharing knowledge through interviews, tours, and draft reviews. They went above and beyond offering photos, stories, advice, reviews, and encouragement. The project team is very grateful to the following people for their help.

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Barrett Goodale, University of Alaska Fairbanks
Bob Sharp, Solar Growing
Bonnie Emery, Alaska Gateway School District
Brad Cox, Dry Creek Logging & Milling Associates
Cameron Willingham, Vertical Harvest Hydroponics
Chad Schumacher, Superior Pellets
Clay Hammer, Wrangell Municipal Light & Power
Daisy Huang, Alaska Center for Energy and Power
Dave Pelunis-Messier, Tanana Chiefs Conference
Don Berberich, Palmer High School
Eric Hanssen, Alaska Native Tribal Health Consortium
Erik O'Brien, Southwest Alaska Municipal Conference
Greg Stuckey, United States Department of Agriculture
Heidi Radar, University of Alaska Cooperative Extension Service and Tanana Chiefs Conference
Ieshia Searle, Thorne Bay School
Jeff Babbit, Alaskan Homegrown
Jeff Werner, Watanuska, LLC
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John Engles, Corbin Creek Farm
Kelli Whelan, Alaska Department of Natural Resources Division of Agriculture
Megan Fitzpatrick, Thorne Bay School
Melissa Chlupach, NANA Management Services
Melissa Sikes, Fairbanks Soil and Water Conservation District
Michele Doyle-Brewer, Cold Climate Housing Research Center
Mike Mosesian, Bells Nursery
Mollia White, Chief Ivan Blunca School
Sally Kieper, University of Alaska K-12 Outreach
Sandee Mayo, Cold Climate Housing Research Center
Scott Sanford, University of Wisconsin
Steve Brown, University of Alaska Cooperative Extension Service
Tim Meyers, Meyers Farm
Tom Zimmer, Calypso Farms
Tony Lee, Alaska Gateway School District
Will Anderson, Kikiktagruk Inupiat Corporation
Will Putnam, Tanana Chiefs Conference

Photo courtesy Corbin Creek Farm, Valdez, Alaska.

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Photo courtesy Meyers Farm, Bethel, Alaska.