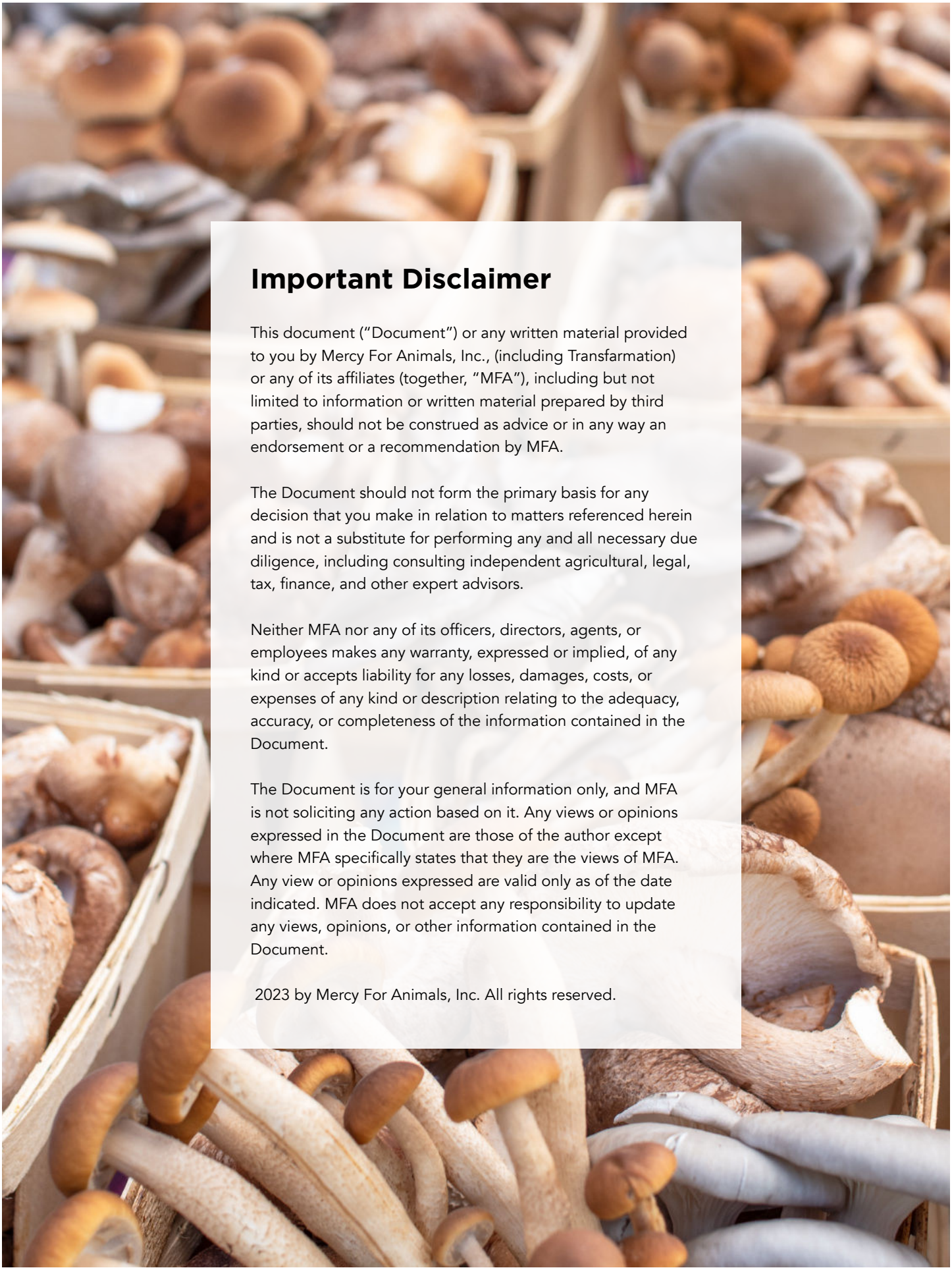
11′ x 24′ x 8′ Site Modification for Specialty Mushroom Cultivation

Transfarmation

MERCY FOR ANIMALS



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Summary

This guide provides recommendations for modifying building infrastructure to create an environment for cultivating mushrooms. The focus is the conversion of a rudimentary storage shed into a suitable controlled-environment mushroom cultivation room for fruiting commercially obtained mushroom bags, blocks, or logs with commercially viable yields and cropping cycles while managing contamination. The designated space will need structural modifications to properly seal and insulate the room, update the electrical system, and ensure plumbing access to the humidification system. Several options and recommendations are provided.

MycoLogic LLC, in collaboration with Transformation, created these materials.

Site Information

- Room inside barn
- Room dimensions: 11 ft. wide x 24 ft. long x 8 ft. high (264 ft.^{2}, 2,112 ft.^{3})
- Floor: concrete
- Walls: combination of two-by-four frame, frame and fiberboard, and sheet metal (barn wall)
- Electrical: 120 AC volts available in room, 240 AC volts capable at electrical panel
- Water: spigot with well water outside the room but inside the barn

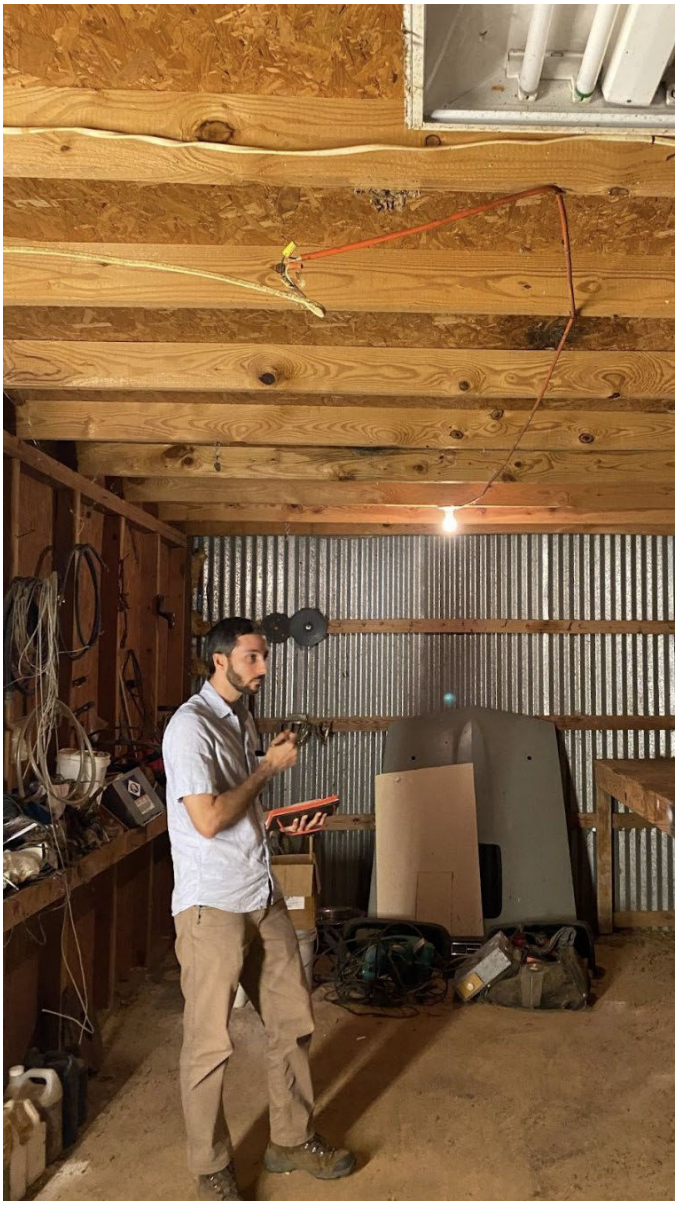

Figure 1. Interior of proposed fruiting room, two of four walls and ceiling framed for insulation.

Figure 2. Large storage shed with internal room for conversion to mushroom fruiting location (red arrow).

Figure 3. Entrance to proposed fruiting room.

Options (Brief)

Several options exist for using or modifying current infrastructure to support development of an environment for mushroom cultivation. This is not meant to be an exhaustive list of possibilities but rather a survey of common options to guide decision-making when determining the most suitable method for developing a cultivation environment for a particular site.

As temperature is a significant growth condition, the room must be properly insulated in order to maintain a consistent temperature between 60°F and 75°F regardless of outside weather conditions. A residential AC unit is sufficient to achieve these temperatures, and proper insulation will reduce overall cooling costs as well as prolong the life of the AC unit.

Humidity is another significant growth condition and must be maintained at a high level. A moisture barrier is essential to maintaining high humidity and preventing escape into surrounding walls that can be damaged by excessive moisture. This moisture barrier will also prevent entry into the cultivation room of microorganism contaminants from outside, which could otherwise contaminate the mushroom growth substrate or mushrooms.

Air exchange is the third significant condition for successful mushroom cultivation. Carbon dioxide (CO_2) generated by the colonizing mushroom fungus and mushrooms will inhibit mushroom formation if concentration is allowed to get too high. Therefore, periodic exhaust of CO_2-laden air and introduction of fresh air from outside are necessary. Inline filter boxes are used to both filter incoming air to remove contaminants and continually filter the air within the cultivation environment to maintain a low level of airborne particulates.

Limiting access to rodents will also be critical, as they can damage the infrastructure, introduce contaminants and pathogens, and consume the growth substrate and mushrooms. All intake and exhaust vents require fine metal mesh to prevent insects and small mammals from entering the cultivation environment. Exhaust vents with flaps or louvers that automatically close when airflow stops are recommended to further restrict entry.

Internet access could enable monitoring of conditions at the site and allow for additional monitoring and control features in the future, but it is not required.

Option 1: Open Floor Plan

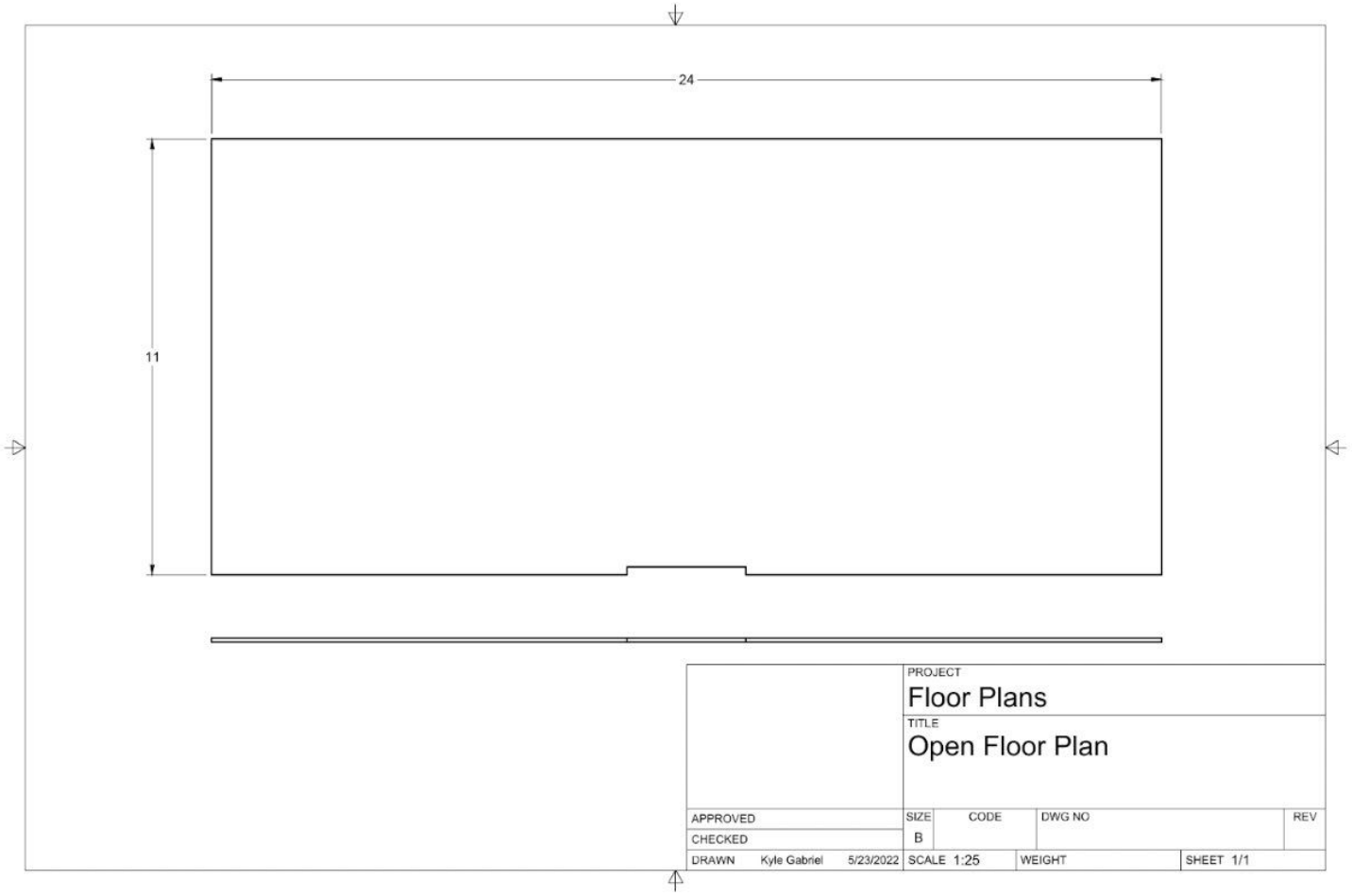

Figure 4. Open floor plan.

To maximize the cultivation area, the entire room can be hermetically sealed (airtight). Walls on all sides and a ceiling should be constructed and insulated. Materials should be chosen to create a water-tight barrier to prevent the high humidity in the cultivation environment from intruding into the walls, which can cause mold growth and rot. The cultivation area will be slightly reduced, depending on the thickness of the materials used to cover the walls. The estimated total cultivation area is 264 square feet.

Pro

- Maximum area for cultivation.

Cons

- Higher cost and complexity of construction.
- Contamination can affect the entire cultivation area.
- Cleaning or decontamination may not align with cropping or harvesting cycle.
- A staging room may need to be constructed outside the cultivation room.
- The life of the AC unit will be decreased because it will be exposed to high humidity.

Option 2: Multiple-Room Floor Plan

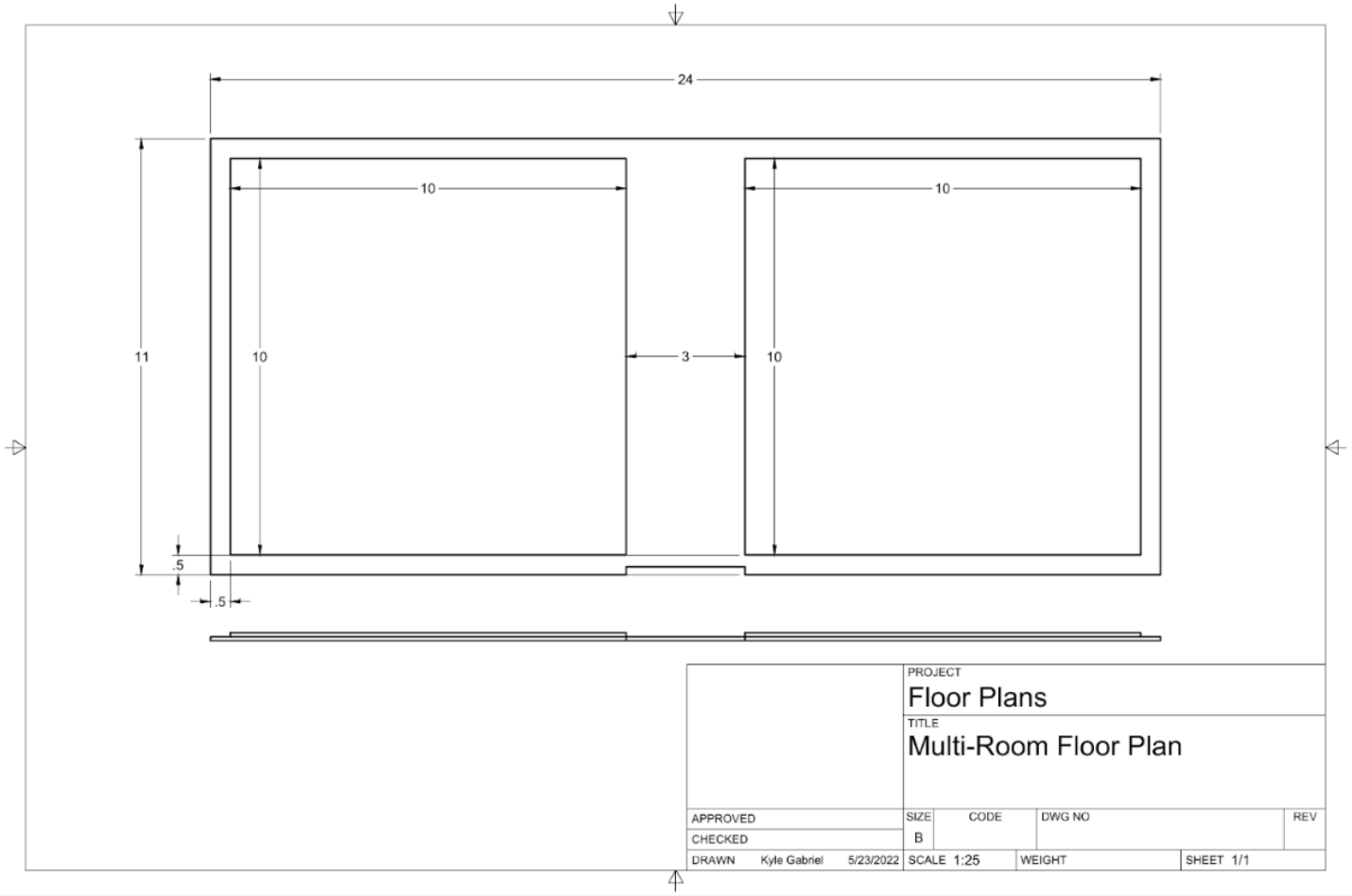

Figure 5. Multiple-room floor plan.

Grow tents are an economical way to set up one or more cultivation rooms within a space. The main room still requires insulated walls to maintain temperatures, but they do not have to be hermetically sealed, as the grow tents themselves will be the hermetically sealed environments where cultivation will occur. The estimated total cultivation area is 200 square feet.

Pros

- Lower cost and complexity of construction.
- Multiple cultivation areas enable use of different environmental conditions to grow different varieties, reduce impact of contamination if isolated to one tent, and offer flexibility with cleaning or decontamination (e.g., clean in a rotating cycle).
- No need to build an additional staging area (the area immediately outside the tents can serve as a staging area).
- The life of the AC unit will be increased because it will not be exposed to high humidity.

Cons

- Less area for cultivation.
- Potentially more environmental control hardware (multiple spaces to regulate).

Options (Detailed)

Vapor Barrier

The use of permanent infrastructure allows for maximization of the cultivation area and can often simplify the required ducting for air movement. Because high humidity can damage wood and other porous materials, walls and ceilings should be covered with panels that are resistant to mold, mildew, and rot. Insulated metal or plastic panels provide both insulation and a vapor barrier. But insulation should also be placed between wall and ceiling joists to improve insulation of the environment. These panels typically feature a tongue-and-groove system to interlock the panels and create a tight seal. Combined with sealant or stripping, these panels render all joints water- and airtight.

TrueCore FRP CleanSeam panel, a fiberglass-reinforced plastic panel.

TrueCore CF partition panel, an insulated metal panel.

More options can be found at Metl-Span.

BRUCHAPaneel WP, partition, liner, and ceiling panels for cold storage applications.

More BRUCHA options can be found here.

Barr 42" x 8' insulated cold storage panel, panels for a sealed modular grow room.

More Barr options can be found here.

MBCI CF45 partition wall, interior wall and ceiling panels.

More MBCI options can be found here.

Grow Tents

Grow tents provide an economical way to create a sealed environment that enables both humidity and carbon dioxide to be contained and controlled. They come in a range of dimensions and are constructed with thick mylar canvas; large zippers for entry; and several drawstring ports for ducting, pipes, and wires. AC Infinity and VIVOSUN are the two largest manufacturers in the industry and produce comparable products, but AC Infinity tents are made with thicker material. Gorilla products are provided for comparison, though their prices are much higher.

AC Infinity CLOUDLAB 811 ($500), 120" x 120" x 80" (10' x 10'), 2000D canvas.

More AC Infinity options can be found here.

VIVOSUN 10x10 ($480), 120" x 120" x 80" (10' x 10'), 600D canvas.

More VIVOSUN options can be found here.

Gorilla Grow Tent 10x10 ($1,170), 10' x 10', 1680D canvas.

More Gorilla options can be found here.

Temperature

Whether installing panels or grow tents, insulation of the room walls is required to maintain a regulated temperature in the main room. A window or mini-split air conditioner is sufficient to maintain cultivation temperatures in the space, and the built-in temperature controller of the AC unit is sufficient to maintain a desired temperature for most varieties (as long as the AC unit is sized properly for the environment). If temperatures below 61°F (the minimum that can be set for most AC systems) are desired for cultivation, the use of a CoolBot is recommended. A CoolBot is also recommended in the construction of a cold-storage room if harvested mushrooms are not immediately transported to market or cold storage elsewhere.

In addition to cooling, many AC systems have the capacity to heat. But if the AC heater is insufficient or absent, supplementation with another heating source may be necessary, such as an electric furnace, space heater, or inline duct heater.

CoolBot Walk-In Cooler Controller ($375), a temperature controller that enables an AC unit to reach temperatures below the minimum set by the manufacturer (typically 61°F). This is useful for designing cold-storage rooms with a residential air conditioner (window or mini-split AC unit). Cold-storage rooms are used for storing harvested mushrooms if they are not immediately taken to market.

Humidity

Most mushroom fungi require a high-humidity environment to form mushrooms. Humidity regulation can be attained with an Inkbird IHC-200 (or similar) humidity controller and a Mainland Mart MHB12 (or similar) humidifier. Since humidity often dissipates over time (due to imperfect seals and dehumidifying effects of air conditioners), incorporating a humidifier into the cultivation area is often necessary. But with grow tents, the use of a dehumidifier in the main room (outside the tents) is advised in order to maintain low humidity levels in the room outside the tents, since excessive moisture can damage walls that are not designed for a high-humidity environment.

Inkbird IHC-200 ($40) humidity controller with humidity sensor and switchable outlet to connect a humidifier. The humidifier is energized until the desired humidity is reached.

Mainland Mart MHB12 ($600) ultrasonic humidifier, 6 lb./hour.

Air Exchange

Carbon dioxide (CO_2) is generated by the growing mushroom fungus. Since CO_2 buildup inhibits mushroom growth, the air in the cultivation environment must periodically be exhausted to bring in fresh air and reduce CO_2 concentration. Since outside air contains contaminating microorganisms, all air entering the cultivation area must be filtered by high-efficiency air filters (e.g., MERV 13-rated or better filters).

Motorized dampers are an excellent way to keep air ducts closed until exhaustion needs to occur, and speed-controlled fans can be used to move air into and out of the environment. Exhaustion can be done with the use of a CO_2 controller or a simple timer. Although higher precision can be achieved using a CO_2 controller, if the sensor fails, the air may be exhausted too often or not often enough. Using a timer gives greater assurance that air will be exhausted periodically, at the expense of precision, since air will be exhausted regardless of the actual CO_2 concentration in the air.

Exhaust Control

CO_2 controllers use a sensor to measure the concentration of CO_2 in the air. The controller energizes one or more devices when CO_2 concentration rises above a user-set threshold. When measured CO_2 falls below the user-set threshold, the devices are turned off.

Timers are an inexpensive and reliable way to generate fresh air exchange and reduce CO_2 concentration in the environment. Because a timer may be in a high-humidity environment or experience a power outage, it should be waterproof and contain a backup battery to retain programming in the event of a power outage.

When using either a timer or a CO_2 controller, fans and normally closed motorized dampers can be powered in unison to simultaneously open a path in the air ducting and turn on the fan to move air.

Inkbird ICC-500T ($160), a carbon dioxide controller with CO_2 sensor and switchable outlet to connect exhaust fans. The fans are automatically energized until the set CO_2 level is reached.

BN-LINK programmable timer, a waterproof timer with backup battery and 15 amp capacity.

Speed-Controlled Duct Fans

Both AC Infinity and Terrabloom make speed-controlled duct fans with diameters from four to 12 inches. These fans can be connected to timers or CO_2 controllers to turn on periodically to exhaust buildup of CO_2 and bring in fresh air. These fans feature a speed controller.

AC Infinity Cloudline S4 ($100) 4" ducted speed-controlled fan.

AC Infinity Cloudline S6 ($120) 6" ducted speed-controlled fan.

AC Infinity Cloudline S8 ($180) 8" ducted speed-controlled fan.

AC Infinity Cloudline S10 ($270) 10" ducted speed-controlled fan.

AC Infinity Cloudline S12 ($370) 12" ducted speed-controlled fan.

Terrabloom ECMF-100 ($80) 4" ducted speed-controlled fan.

Terrabloom ECMF-150 ($100) 6" ducted speed-controlled fan.

Terrabloom ECMF-200 ($160) 8" ducted speed-controlled fan.

Terrabloom ECMF-250 ($230) 10" ducted speed-controlled fan.

Terrabloom ECMF-315 ($340) 12.3" ducted speed-controlled fan.

Motorized Dampers

Motorized dampers enable the airway in ducts to be opened or closed electronically. They are useful for redirecting airflow within a duct system and opening and closing airways for intake and exhaust. Dampers come in four- to 12-inch diameters and are normally open or closed.

*NO = Normally open, NC = Normally closed

Suncourt ZO206/ZC206 ($70) motorized damper for 6" duct, NO/NC.

Suncourt ZO208/ZC208 ($70) motorized damper for 8" duct, NO/NC.

Suncourt ZO210/ZC210 ($75) motorized damper for 10" duct, NO/NC.

Suncourt ZO212/ZC212 ($75) motorized damper for 12" duct, NO/NC.

S&P MD4 ($65) motorized damper for 4" duct, NC.

S&P MD6 ($65) motorized damper for 6" duct, NC.

S&P MD8 ($75) motorized damper for 8" duct, NC.

S&P MD10 ($90) motorized damper for 10" duct, NC.

S&P MD12 ($95) motorized damper for 12" duct, NC.

Inline Filter Boxes

Air filtration is necessary to remove contaminants from the air drawn into the cultivation environment from outside as well as from the air within the cultivation environment. Inline filter boxes enable airflow within a duct to be filtered and should be installed on the air-intake duct as well as the air-circulation duct.

AC Infinity AC-AFB4 ($100) 4" inline air filter box with one high-efficiency filter.

AC Infinity AC-AFB6 ($120) 6" inline air filter box with one high-efficiency filter.

AC Infinity AC-AFB8 ($150) 8" inline air filter box with one high-efficiency filter.

AC Infinity AC-AFB10 ($170) 10" inline air filter box with one high-efficiency filter.

Fantech FB 6 ($105) 6" inline duct filter box with 10" x 20" x 1" (nominal) MERV 13 pleated filter.

Fantech FBRF 6 ($30), FB 6 MERV 13 replacement filters, 10" x 20" x 1".

Additional inline filter boxes can be found here.

Wall-Mounted Vents

Vents are the interface between internal and external environments. They mount to a wall and provide a connection for vent ducting and coarse filtering to prevent insects and other animals from entering the duct, and they may include flaps or louvers that close when no air is flowing to further seal the duct. A minimum of two vents are typically used per indoor environment, one for air intake and one for air exhaust.

Fantech FML 8 ($45) 8" fixed metal supply/exhaust hood for round ducts.

Fantech FML 10 ($60) 10" fixed metal supply/exhaust hood for round ducts.

Fantech FML 12 ($85) 12" fixed metal supply/exhaust hood for round ducts.

Primex WCL701 ($35) 7" or 8" collar with screen and removable backdraft dampers.

Additional wall vents can be found here.

Example Designs and Materials

Design 1: Open Floor Plan

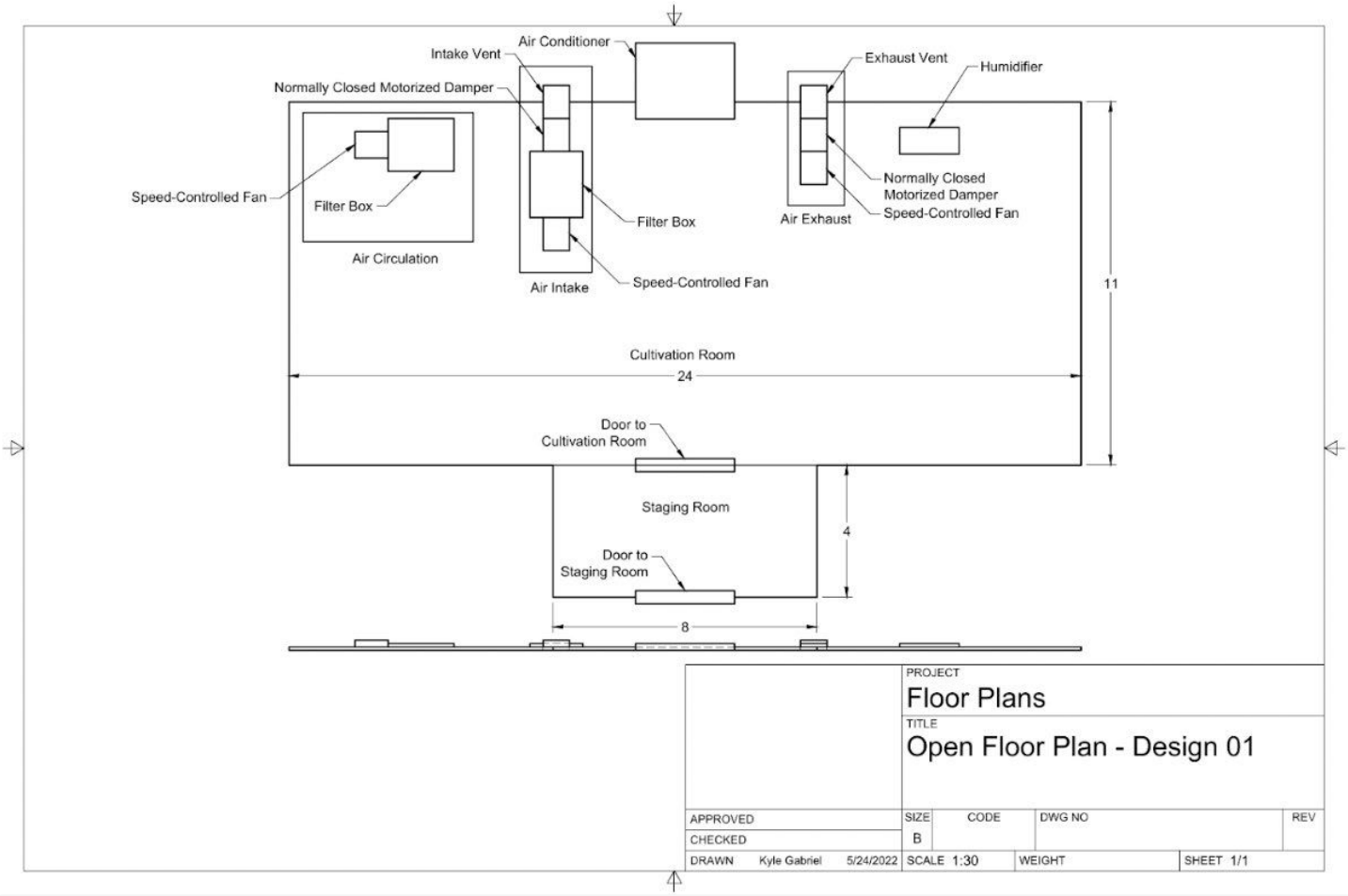

Figure 6. Open floor plan.

This design maximizes the growing area in the cultivation environment by utilizing the entire floor space for cultivation. This option increases the complexity of construction by requiring paneling to protect the walls from moisture and maintain high relative humidity in the room. This design also allows contaminants to enter when the main door is opened, so building a smaller room that can serve as a staging area is recommended. The staging area in the floor plan is for demonstration purposes and not necessarily the recommended size.

Plan Features

- Insulated and hermetically sealed room to maintain temperature and high humidity
- Window or mini-split AC system
- Intake vent, damper, filter box, and fan
- Exhaust vent, damper, and fan
- Circulation fan and filter box
- Humidifier
- Staging area outside the cultivation area door (optional)

Design 2: Multiple-Room Floor Plan 1

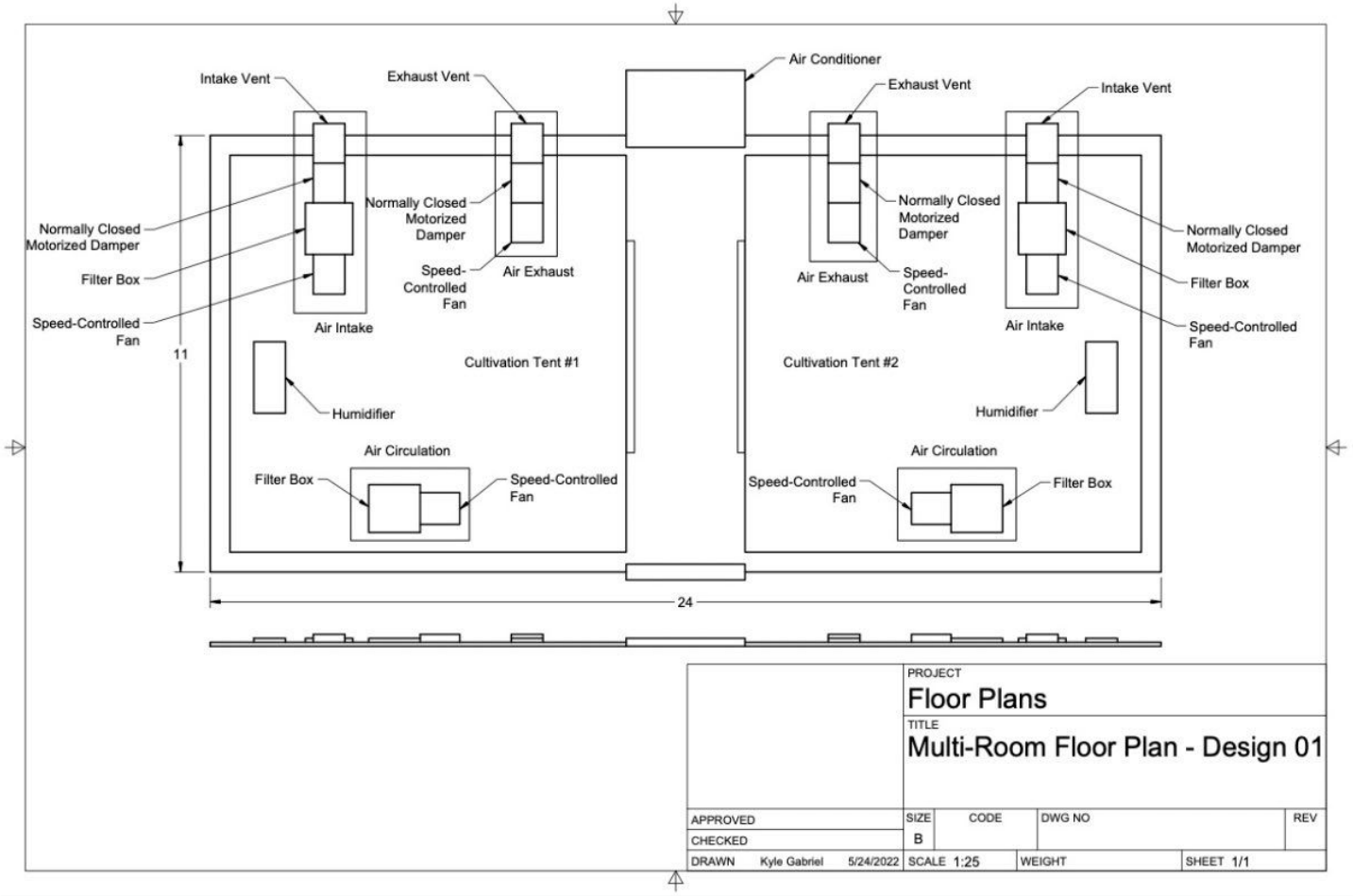

Figure 7. Multiple-room floor plan with individual vents.

This design separates each grow tent into its own completely independent environment. If one tent has an airflow or a humidity issue, the other tent is likely unaffected because of the redundancy of environmental control systems.

Plan Features

- Insulated room to maintain temperature
- Window or mini-split AC system
- Two 10 ft. by 10 ft. grow tents spaced six inches from the walls
- Each grow tent should have the following:
  - Intake vent, damper, filter box, and fan
  - Exhaust vent, damper, and fan
  - Circulation fan and filter box
  - Humidifier

Design 3: Multiple-Room Floor Plan 2

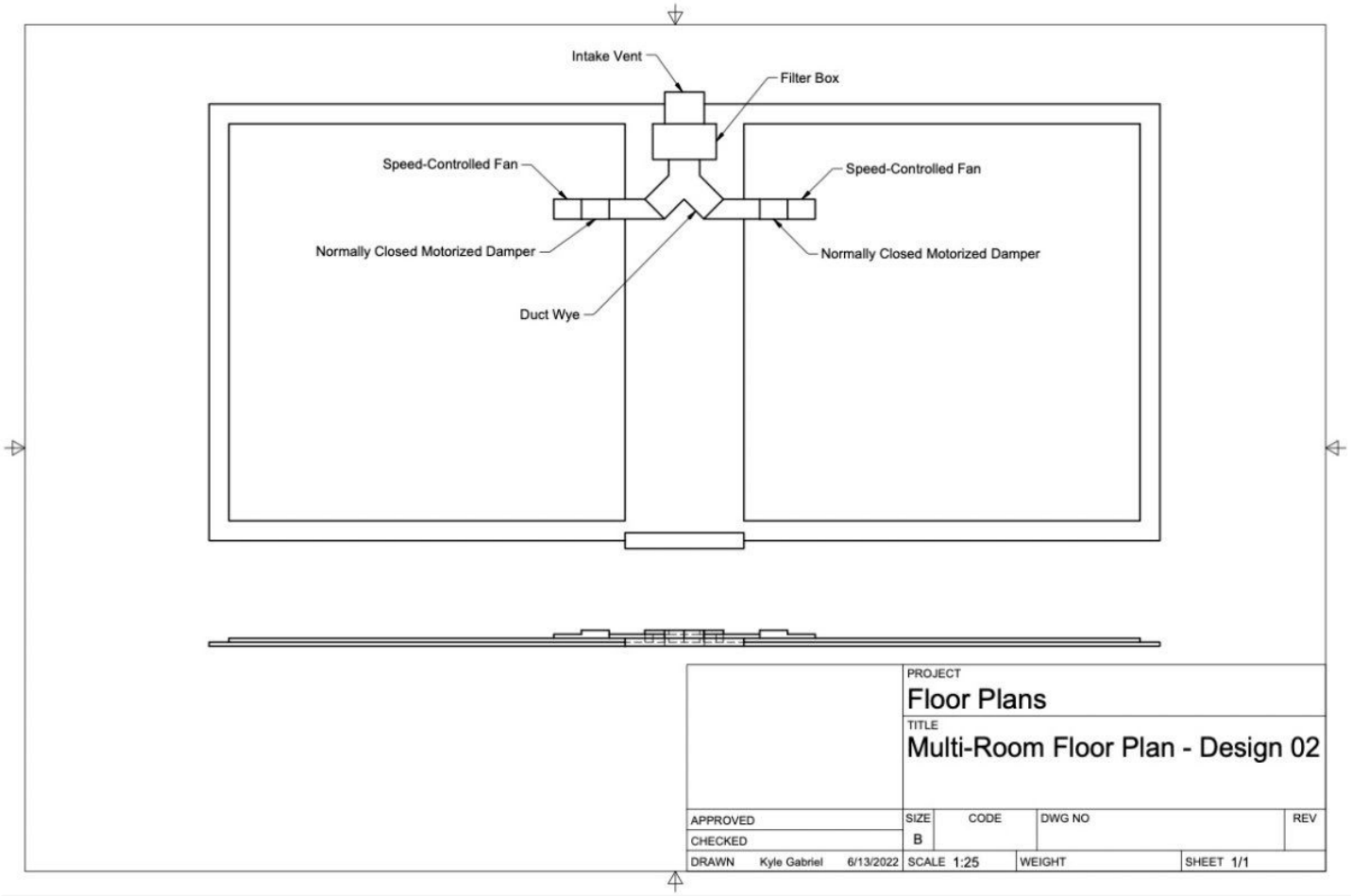

Figure 8. Multiple-room floor plan with shared vents.

This design is a modification of the first multiple-room floor plan. It reduces the number of vents from four to two, allowing both grow tents to use the same intake and exhaust vents and intake filter box by splitting the airflow with duct wyes. The diagram above shows only the intake ducting system, but the exhaust ducting would be similar (only without the filter box). This reduces cost and the number of vent holes in the wall but also introduces the possibility of reduced airflow due to the use of wyes. Therefore, if using timers to exhaust air, staggering the timed exhaust cycles between tents is recommended. If using CO2 controllers, staggering may not be possible, since exhaustion will occur whenever concentration is detected above the set threshold.

Plan Features

- Insulated room to maintain temperature
- Window or mini-split AC system
- Two 10 ft. by 10 ft. grow tents spaced six inches from the walls
- Single intake vent and filter box with one wye to split airflow to each tent
- Single exhaust vent with one wye to split airflow to each tent
- Each grow tent should have the following:
  - Intake damper and fan
  - Exhaust damper and fan
  - Circulation fan and filter box
  - Humidifier

Additional Considerations

Because of the nature of mini-split AC units, they maintain a hermetic seal better than window AC units. If one is constructing a hermetically sealed room rather than using grow tents, the pipes of a mini-split AC system that need to penetrate the wall are significantly easier to seal than the large opening for a window AC unit. Window AC units also have crevasses surrounding the internal AC components, necessitating additional insulation steps and potentially creating openings for insects to enter. If using grow tents, a window AC unit is a good option, as it's easier to install and less expensive than a mini-split. Mini-split AC units are also less compatible with a CoolBot, if very low temperatures are desired.

Electrical components exposed to a high-humidity environment will eventually degrade and fail. Therefore, components exposed to the high humidity in a cultivation environment, including fans, dampers, heaters, humidifiers, and AC units, should be considered consumable materials that will need to be replaced every few years. Keeping replacement parts on hand is recommended.

Flying insects can infest a mushroom cultivation area and significantly reduce mushroom formation by transmitting contaminating microorganisms to mushroom fungi, causing premature aborting of primordia and reducing mushroom yields. They can persist by feeding and breeding on mushroom fungi and growth substrate. Because they can easily enter the cultivation environment when a grower opens the main door, constructing or designating a staging area is recommended. This staging area can serve as both an intermediary room to inspect for insects that may have entered and an area to organize materials (e.g., growth substrate), such as when moving materials into and out of the cultivation area. Setting up insect traps in the staging area is also recommended.

When choosing ducting size, larger-diameter ducting and fans can move air faster than smaller-diameter ducting and fans but will occupy more space and increase costs.

If using duct wyes, ensure the area of the single opening is roughly equal to the combined areas of the two split openings. If the areas are not similar, air will be constricted, and reduced airflow will result. For example, a wye with one 10-inch opening and two four-inch openings will have areas of 78 square inches (10") and 25 square inches (4" + 4"). Since the area of the four-inch ducts is significantly less than that of the 10-inch opening, airflow will be restricted going through these four-inch openings. If six-inch openings were chosen rather than four-inch ones, the combined area would be 56 square inches (8" + 8") and result in an increased airflow through these openings.