Jim Schultz of Red Shirt Farm in Lanesborough, MA built his climate battery greenhouse in the fall of 2017 to save propane costs and trial an elegant solution to a more climate-friendly strategy for winter growing in New England.

**What is a Climate Battery?**
A climate battery is a ground to air heating system comprised of a series of underground tubes that circulates air several feet below the soil surface. The circulating air helps regulate temperature and moisture in the greenhouse, minimizing (or eliminating) the need for propane heat in winter as well as helping reduce disease pressure by keeping air moisture low. The climate battery is a unique system built using low-cost materials, requires minimal maintenance and can be fitted to any size tunnel. Jim Schultz’s high tunnel is 30 feet x 72 feet.

**How Does It Work?**
As the sun heats the air in the greenhouse during the day, the climate battery fans push the warm air from high inside the greenhouse several feet underground. The warm, moist air is pushed through a series of underground tubes transferring heat and moisture to the subsoil, essentially charging the large underground soil reservoir with latent heat. Cooler, drier air emerges into the greenhouse. When the sun isn’t shining or when it is especially cold, the climate battery fan system can be turned on to supply warm air from the heat stored underground to the rest of the greenhouse. The underground tubing of the climate battery is 3-4 feet underground.

**Some Additional Resources:**
- **Design and Consulting:**
  - Central Rocky Mountain Permaculture Institute • [https://crmpi.org/](https://crmpi.org/)
  - Climate Battery Calculator • [www.ecosystems-design.com/climate-battery-calculator.html](http://www.ecosystems-design.com/climate-battery-calculator.html)
  - CERES Greenhouse Solutions: Customized Climate Battery Design • [www.ceresgs.com](http://www.ceresgs.com)

- **Greenhouse Construction:**
  - Vineripe Greenhouse Construction (Roxbury, VT) • [https://www.vineripe.net/](https://www.vineripe.net/)

- **Climate Battery Specifics:**
  - The Forest Garden Greenhouse by Jerome Osentowski
  - Presentation PDF by Jim Schultz for his 30” x 72” tunnel • [bit.ly/climatebatterypdf](http://bit.ly/climatebatterypdf)

- **Potential Grant Information:**
  - Berkshire Agriculture Ventures (applicable to those in the Berkshires) • [https://berkshireagventures.org/funding-assistance/grants/](https://berkshireagventures.org/funding-assistance/grants/)
  - Energy Efficiency Division of MA • [https://www.mass.gov/energy-rebates-incentives](https://www.mass.gov/energy-rebates-incentives)

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**Figure 5:** Inside the climate battery, newly installed just in time before the snow. Notice the black air intake riser to the left (before mylar ducting is attached to draw warm air from higher up in the high tunnel).
Components of a Climate Battery
Climate Batteries have relatively few, inexpensive parts. Here are the materials that Jim used in constructing his climate battery inside his 30’ x 72’ tunnel. See the diagram of the Climate Battery cross-section, overhead and lengthwise view to determine the placement of each of the components listed here.

**Heat Exchange Tubing:** Jim’s tunnel used 3570 feet of 4” perforated ADS plastic drainage pipe with sock cover

**Manifolds:** Three lengths at 25’ 6” of 12” ADS N12 dual-wall HDPE drainage pipe

**Risers:** Vertical sections of pipe for pulling air in and out of underground tubes. 15” ADS dual-wall HDPE drainage pipe: 2 pieces at 6’8” and 1 piece at 4’11”

**Rigid Foam Insulation:** Insulating the ground under the high tunnel is absolutely essential for the Climate Battery to function efficiently. Twenty-six sheets of 4’ x 8’ x 2” foam board were used.

**Intake Riser Extension Ducting:** 18” flexible Mylar ducting

**Intake Fans:** Two 12” greenhouse HAF fans

**Variable Speed Fan Controllers:** Two

**Climate Battery Controls:** Jim used hard-wired commercial greenhouse thermostats to monitor and manage his climate battery system. Wireless network monitoring is available, but must be built able to withstand a greenhouse environment.

**Extra Components To Consider:**
- **All-in-one controller:** Have all monitoring equipment in one set of controls. This option is more expensive, but simpler to use.
- Automated roll-up sides: Automate temperature regulation for your tunnel.

**Solawrap plastic:** Solawrap is a higher grade plastic, a “bubble wrap” for your tunnel with increased insulation rating, less glare, easier to install, longer lasting (20 + years), and extremely high rating to withstand damage (including hail, high wind and snow).

**Costs:**
These costs are, of course, unique to Jim Schultz’s site, location, and design, however costs will be comparable to other New England farms.

- Material expenses: $6,301.14
- Service expenses (Excavation, Labor, Engineering Design): $5,832.00
- Grant support: $9,118.00
- **Total cost:** $3015.14
- **Propane Savings estimated:** $1400/year ($1.90/gal)
- **Payback period with grant:** 2.15 years; without grant: 8.6 years

**Design Considerations:**
- **Underground Heat Exchange Tubing Length:** 25-35’ is what is recommended to maximize heat transfer underground and take advantage of latent heat of condensation for the climate battery design.
- **Radon Testing:** Do a radon test to ensure your underground soil is radon free.

**Soil type considerations:** Heavier soils will store more heat allowing for closer heating arrays while lighter sandy soils require more spacing between underground tubes. A sandy loam is ideal for the spacing in the design represented. Soil with too much clay (more than 20-25%) can be problematic for climate battery systems as water condensing underground can sometimes cause a clay “shell” to form around the underground heat exchange tubing, ultimately clogging the system.

**Depth:** In climatic zones 4 and 5, the heat exchange tubing array is buried 3’-4” for optimal performance. Going deeper is prohibitively expensive.