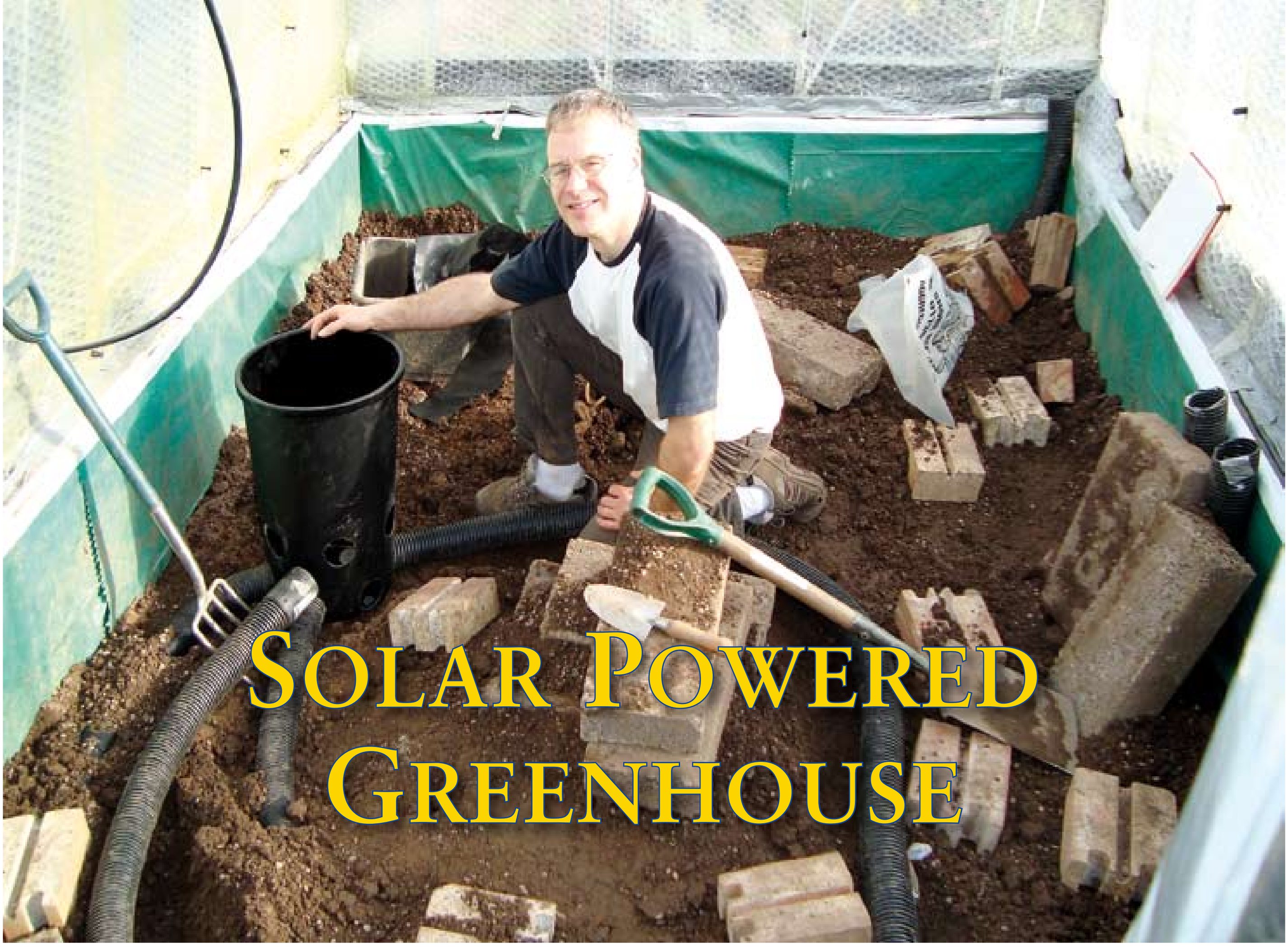


Solar Powered Greenhouse

Andrew Collins describes a simple fossil fuel free heating and cooling system for year-round growing in an ordinary garden greenhouse.

Controlling temperature swings in small garden greenhouses is notoriously difficult. Greenhouses are liable to overheating in full sun and, of course, most will do little to keep out a hard frost. Among those who are not keen on using electric or gas heaters in greenhouses there has been a resurgence of interest in 'solar greenhouses' using various methods to trap the solar energy striking the greenhouse and release it at night. At its simplest, the heat storage medium consists of barrels of water, but in a garden greenhouse these can take up a large proportion of the growing space.

The Experiment

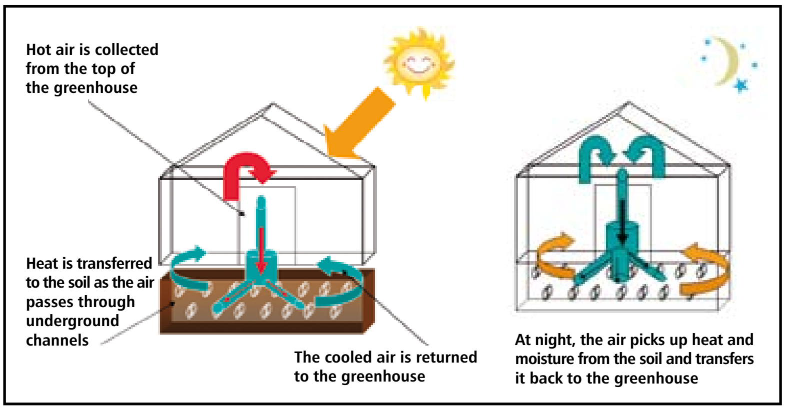
I describe here an experiment I've done, adapting an elegant idea that has been used with some success in large greenhouses and polytunnels.[1,2] In the Subterranean Heating and Cooling System (SHCS), the entire mass of the soil and sub-soil under the greenhouse is used to store heat. Exchange of heat between the air and the soil is enabled by a network of buried perforated pipes through which air is forced via solar powered fans. Thus, on sunny days warm air gives up its heat to the soil as it passes though the pipes and returns to the greenhouse cooler, helping to control the temperature. At night, if the temperature falls below a set point the fans are activated again to warm the air as it passes underground. In order for this to work effectively, the sides of this heat store are insulated.

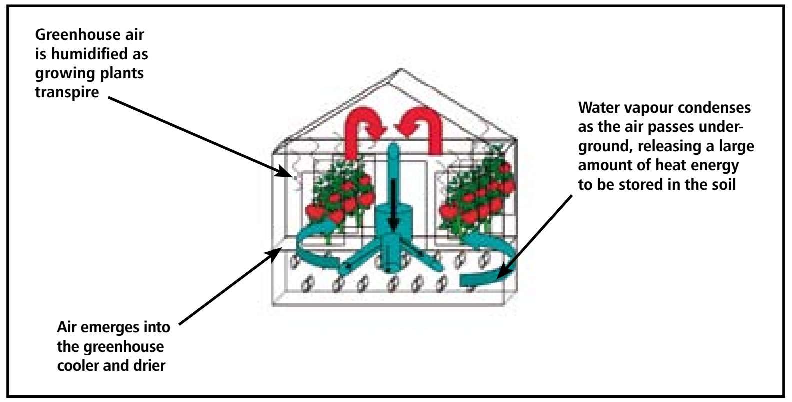
One of the attractive features of SHCS is that the plants, which are grown directly in beds in the greenhouse soil, play an active part in the heat recycling process. As they transpire water is taken up from the roots and evaporated into the air. This phase change from water liquid to vapour is what actually

Above: The author installing air ducting under the floor of his greenhouse.

Left: The greenhouse in winter.

Below: Heat storage and release in SHCS.





Above:
The magic of phase change – the key to heat transfer in SHCS.

absorbs much of the solar energy striking an SHCS greenhouse full of growing plants. The moisture-laden air cools during its subsequent passage underground and the so-called 'dew-point' is reached at which water vapour condenses, giving up a large amount of heat energy to the subsoil in doing so. The transfer of energy that occurs in this phase change is many times greater than simple conductive transfer alone, and is the reason why SHCS greenhouses are intended to be operated at relatively high humidities.

If you don't mind a bit of digging, a home-made SHCS is easy to install, and here is how I put together my system under a standard, second-hand aluminium greenhouse. Some of my components (land drain pipe, solar panels) were bought new, and others (fans) were salvaged from other applications.[3]

Design & Installation

My site is a suburban garden on an east-facing slope in Perthshire. The soil is heavy clay, so a few 90cm (3ft) deep holes were dug beforehand and filled with water to check for drainage. (The water drained away overnight indicating that the site was suitable).

My greenhouse is an aluminium-framed single glazed one recycled from a neighbour's garden. The base area is 2.43 x 3.66 (8 x 12ft) and the internal volume is about 19m^3 (204ft^2).

A proper masonry foundation would be best, ideally to a depth of 90cm (3ft) – in my case I hit large rocks and a land drain at 60cm (2ft). Aircrete has insulating properties and might be a good material to use for this. My foundation was made from railway sleeper-type timbers to a depth of 60cm (2ft) and lined on the inside with 50mm (2in) extruded polystyrene (EPS) board (ordinary polystyrene loses its insulating properties when waterlogged.

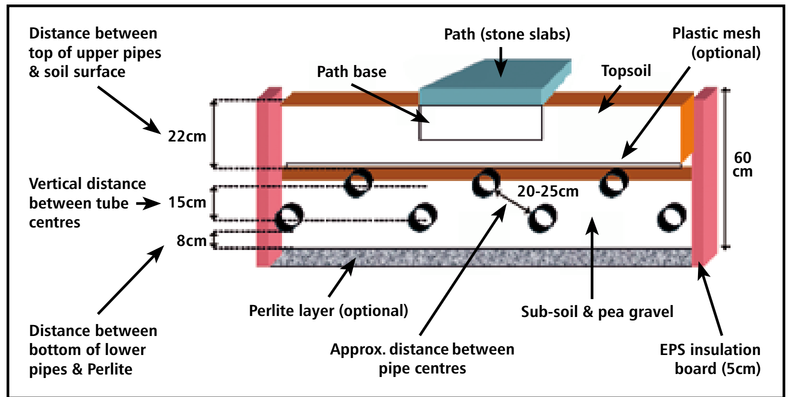
The land drainage pipe was cut into twelve 5m (16.4ft) lengths (60m/197ft total) of 80mm (3in) diameter and the pipes arranged in two vertical layers with the top of the highest layer approximately 22cm (8.7in) from the soil surface. The average vertical spacing was about 15cm (6in) between pipe layers (measured on pipe centres) with an average overall spacing of 20-25cm (8-10in) between pipes.

A layer of strong plastic fencing mesh was laid over the topmost pipes to prevent inadvertent puncturing of the pipes during cultivation of the top soil.

The pipes were buried in the sub-soil in a curved radial pattern. To achieve this trenches would normally be dug with a narrow spade, in my case I excavated the whole soil mass. The pipes were held in place while backfilling with a mixture of sub-soil and pea gravel (sub-soil alone would have been fine). An excavated hole also made it possible to insulate underneath the soil mass as well with a layer of about 70mm (2.75in) of perlite (but this is not essential and may even be a disadvantage in summer). Each pipe connects to a part buried central 'plenum', made, in this case from a plastic bullet bin, and they exit at soil level around the side walls of the greenhouse. The exits are screened with wire mesh to keep out unwanted rodent visitors. Solar powered fans are mounted on the top part of the plenum and these draw down warm, moist daytime air from near the top of the greenhouse through an improvised duct.

Centre:
Air duct and fan unit on top of the plenum chamber.

Below:
Section diagram showing sub-soil pipe spacing (not to scale).



Powering the Fans

Whereas the underground pipes are hard to modify once in place, the above-ground parts are easy to modify to achieve an appropriate air turnover.[4] I was keen to use only solar power, and this arrangement turns out to be very simple to set up, since most 12V DC axial fans will happily run directly from solar panels designed to charge 12V batteries. Very little power is required to run the system, but the fans and power source need to be approximately matched. For example, a 13W, 12V solar panel array will power two 5W, 12V fans connected in parallel. In practice, the solar panels can be 'oversized' slightly in relation to the fans (e.g. 12W or 13W in the case above). The fans are mounted on a 'plenum' made from a food storage drum. The bottom of the drum has been sliced off to fit over the buried part of the plenum to which the pipes are connected. The removable top duct is made from two small plastic bins.

Another solar panel charges a 12V, 12 amp-hour leisure battery which powers the fans at night when the temperature falls below a set point. (An inexpensive charge regulator is included to prevent overcharging, but is not strictly necessary.) A simple bimetallic switch made from a winemaking thermostatic heater determines the temperature at which the fans switch on at night to pump warmer air into the greenhouse (generally set to about 6-7°C).

Does it Work?

My latest installation was up and running at the beginning of March 2009. I used bubble-wrap to mitigate the huge night-time heat losses (which, from this type of greenhouse would challenge even a large conventional heater). Sub-soil heat gains were as much as 2°C on a sunny spring day and by March 21st the average greenhouse soil temperature at a depth of 76cm (30in) was 16°C versus 6.5°C in the soil outside, representing stored heat of around 49kW hours. Although there were only light night-time frosts in March/April the system maintained the internal greenhouse temperature at above 5°C for the whole period allowing me to bring on lots of seedlings. Last season I was able to grow greenhouse crops of runner beans which ripened in late May. As the system relies on growing plants to generate enough humidity, misting and light shading is required in late May and early June before the summer crop plants get big enough to play a full part in temperature regulation. At the time of writing (late July) the greenhouse is full of tomatoes, cucumbers, figs and melons, and the temperature settles nicely on sunny days at 28-32°C with a relative humidity of about 60% and the shading is no longer needed. A nice extra benefit of this set-up is increased air circulation inside the greenhouse

Postscript

With all the digging required and with insulation, fans, solar panels etc to acquire, SHCS certainly isn't the easiest way to keep frost out of a greenhouse! A 3kW electric heater would have done the job nicely. Let's say it was a personal choice.

References

1 www.sunnyjohn.com

2 www.roperld.com/science/YMCAsolargreenhouse.htm

3 www.cpssolar.co.uk

4 'Test of Technologies for Affordable Solar Greenhouses'–Dov Strauch MA; Appalachian State University, August 2008.

Andy Collins been a research scientist for much of his career, and is now a college lecturer and school teacher. He is interested in home-made renewable energy projects, and particularly likes the idea of re-employing industrial artifacts (in this case: fans, polypropylene drainage pipe, batteries) in renewable energy projects on a DIY scale. SHCS is a proven technology on a big scale and is an elegant way to manage the large solar gains and heat losses from a glasshouse or polytunnel without large inputs of fossil fuel energy. However, very few attempts have been made to test small working prototypes and see whether they could make a worthwhile contribution to heating/cooling a greenhouse in a UK climate.

Andy Collins can be contacted by email at: ac010a1591@blueyonder.co.uk

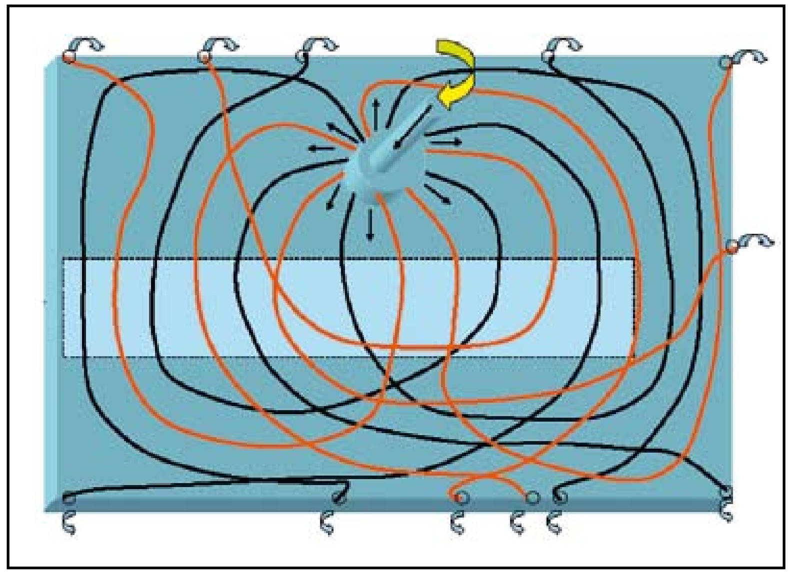
Wiring diagram, results graph and more photographs overleaf.

Above:
Some of the test equipment used to monitor temperatures and airflow.

Left 1:
One of the air ducts and an early crop of lettuces.

Left 2:
Two 12V fans mounted above the plenum chamber draw air through the system.

Below:
Approximate plan of the sub-soil pipe layout.



Above: Connected up duct work ready for burying.

Top right: Air ducts and insulated soil and glass.

Right: Wiring diagram.

Far right: Thermostat plus plastic box housing the battery and controller.

Right & bottom right: The greenhouse in Spring. The solar panels are just visible on the roof.

Below: Sample time, temperature graph.