GREENHOUSE CLIMATE PHYSICS

Words by Elly Nederhoff, Crophouse Ltd

Greenhouses have been used for centuries for protecting plants from the elements, as well as overwintering subtropical plants, bringing harvest forward, producing out of season and out of normal climate zones.

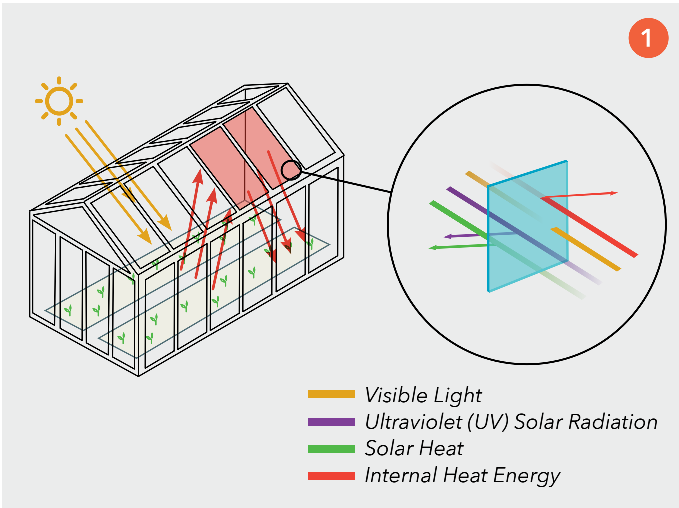
Over time they developed into efficient production facilities where growing conditions are optimised. Temperature, humidity, CO_2, light and shade, air movement and root zone conditions can be controlled by heating, venting, screening, fans, fogging or misting and other methods. This article outlines some physical principles as background to energy-wise climate control in greenhouses, to be discussed in later articles.

Solar radiation

Solar radiation, or sun rays, provide the light and warmth that are crucial for plant growth. **Nearly 50% of solar energy is shortwave radiation (visible light)**, and the other nearly **50% is longwave radiation (heat)**, and a very small part is UV (ultraviolet) radiation. Light is radiation that we can see and that plants need for photosynthesis and growth. Heat is something we can't see, but we feel it. It is important to take into account the difference between solar radiation, light and heat. There can easily be too much **heat**, as too hot is harmful, but it is not often plants get too much **light**. Obviously in solar radiation they go hand-in-hand.

Because plants need light, we cover greenhouses with a translucent material such as glass or clear plastic (polyethylene, polycarbonate, etc). Glass and clear plastics transmit light very well. (To say they transmit light means that they let light go through them). In contrast, for heat (longwave radiation) glass has a very poor transmission; and most plastics have a moderate to low transmission. Ultraviolet radiation is considerably blocked by most materials. Rafters and other construction elements block a small part of all incoming sun rays. It is important that the roof allows plenty of light to come into the greenhouse, but partly blocks heat from coming in. The transmission can be altered by using special covering material, or coatings or screens. And there are some benefits to be gained from the proper use of screens.

Greenhouses trap heat

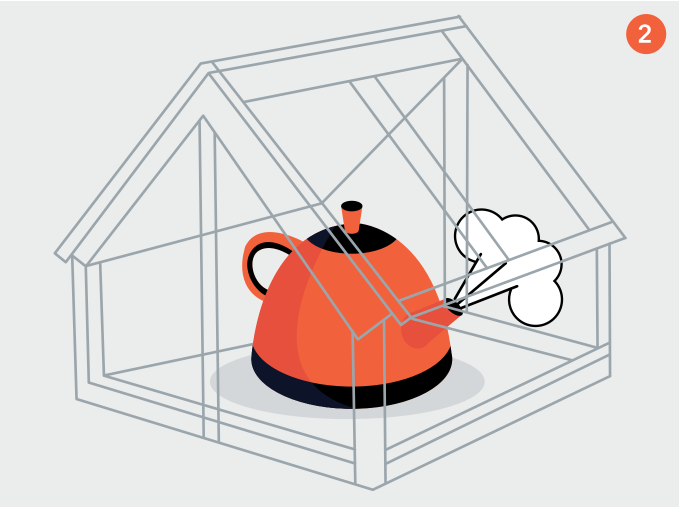


Solar radiation entering the greenhouse warms up the soil, structure, roof, plants and indirectly also the air in the greenhouse. The first advantage is that a greenhouse lets in a lot of solar energy, much more than a building. The second advantage is that a good part of the incoming **light** radiation turns into **heat** radiation. The third advantage is that glass strongly blocks heat radiation, and this works in both directions, so heat radiation stays inside. This also means that heat radiation coming from heating pipes (in cold periods) stays mostly inside. On top of that, warm air cannot easily escape through the roof, unless it is leaking or vents are open. This all means that a greenhouse roof acts as a blanket that traps the heat. The heat trapping ability of a greenhouse is most obvious on a sunny winter's day: without heating but with vents closed, it is much warmer inside than outside. The heat trapping is not perfect though. In cold winter conditions, it may be necessary to use a good energy screen as an extra blanket.

Radiative & convective heat

Radiative heat was discussed above: it is the warmth beaming from the sun. It is also the warming rays beaming from a hot surface such as a radiator or heating pipes. Convective heat is different: it is warmth that is present in a mass of water or air, that can flow from one place to another. For instance, hot air blown out by an electric fan heater is convective heat. Heating pipes in a greenhouse produce both radiative and convective heat. The latter is because air masses flowing along the hot heating pipes get warmer. A warm air mass is convective heat.

Latent heat



A third form of heat is latent heat, which means hidden heat or hidden energy. Latent heat cannot be felt, unlike radiative heat and convective heat. **Latent heat is the presence of water vapour in the air**. Note that water **vapour** is invisible, unlike fog or mist that consists of small visible water droplets.

The concept of latent heat can be understood by thinking of boiling water in a kettle. After some time and after spending a lot of energy (electricity or gas), the water will be completely gone, evaporated. Evaporation is changing from liquid water to water vapour. The fact that the kettle used so much energy for evaporation shows that water vapour is very energy rich. Since water vapour is invisible, it is called latent energy.

If the evaporation takes place in a small room (or glasshouse), we will see water dripping from the windows and walls. This is condensation that happens when humid air touches a colder surface. By the way, condensation releases energy, but that is hard to visualise. Understanding the difference between radiative, convective and latent heat helps to take smart energy saving actions.

Air humidity

Latent heat leads to the topic of air humidity. Air humidity can be expressed in various ways: relative humidity (in %), absolute humidity (in g/m^3), dewpoint (in °C), vapour pressure deficit (VPD), and more. Climate control computers can use any of these forms of humidity, often for different purposes. This will be the topic of a following article, as a starting point for a consideration of energy-wise climate control.

1

Heat Trapping
Solar rays enter the greenhouse, where short-wave radiation (light) turns into long-wave radiation (heat). The warmth is more or less trapped inside the greenhouse because glass does not transmit it very well.

2

Latent Heat
Evaporation of water requires a lot of energy. Therefore water vapour in the air represents energy. Real water vapour is invisible and is therefore called 'latent energy'.