THE SUNCATCHER PASSIVE SOLAR GREENHOUSE®

Science principles behind the design, development and management of a year-round, free-standing passive solar greenhouse.



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Disclaimer

This book is a summary of our research and work to date. Some of the photos included in the text were of "research models" with design components we found to be not as good as other designs (e. g. vent placement & north roof angle), which we changed in future models. We learned by doing, both from the flaws in past research and designs and in our own models.

We've tried to enrich this book with quotations and references to other texts to expand on the concepts being discussed. Please realize the other texts may also include some conceptual misinformation (e.g., plastic containers being used for thermal mass, angle placement of south facing glazing). When something is questionable, we suggest you look closely at their data.

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Preface

The sustainability movement is encouraging more locally grown food to reduce energy use and improve food quality. The uncertainties related to climate change (extreme heat, extended droughts, floods, pests, diseases, etc.), are affecting traditional areas where the majority of the crops we eat are grown, affecting food availability and prices. It would, therefore, be wise for communities to become less dependent on food from elsewhere, and (re)invest in local/regional food production, processing and marketing as was the norm before the industrialization of agriculture after World War II.

Growing flowers, herbs, fruits, and vegetables year-round is, of course, challenging in areas with short growing seasons and harsh winter climates. In those environments, high tunnels and greenhouses are essential to extend the growing season or allow growing year-round for many crops. Conventional greenhouses and high tunnels perform these functions, but at great expense of fossil energy to cool the structures in summer and heat them in the winter. In contrast, passive solar greenhouses have been designed and constructed to be energy-efficient, attractive, versatile, and flexible structures, achieving greater growth at less than 10% of the ongoing energy costs. Powered by the sun and properly managed by their owners, they heat, store that heat and produce a variety of crops (vegetables, small fruits, flowers, herbs, ...) as well as providing a unique space for relaxation and gathering with family and friends.

Passive solar greenhouses (PSGs) achieve their energy savings through the use of thermal mass, insulation, glazing, and an east-west orientation of the long axis of the structure to collect, convert, and store the low-angle winter sun's energy for heating the structure 24 hours a day. The passive solar process minimizes the PSG's interior temperature fluctuations without venting the excess solar heat during the day, instead storing that heat to be used at night. These characteristics distinguish PSGs from conventional greenhouses, providing as much as 90% savings in energy use for growers. Lower energy bills will increase profitability and ability to compete with large-scale growers using fossil fuel intensive methods in states and countries with no or milder winters. Growing locally also reduces the large costs associated with transportation and packaging. As a very important part of sustainable agriculture, energy efficient passive solar greenhouses allow local producers to grow year-round and remain competitive in a market that favors quantity, efficiency, profit and cheap over quality, equity, sustainability, and local/regional self-sufficiency. If increasing local food production is the answer to our modern problems of food, fuel, and CO_2 emissions, the PSG is a key player in fostering their growth and prosperity.

We want to be clear up-front that a PSG costs more to build than a standard greenhouse or high tunnel (with or without some passive solar adaptations), given the better materials used, more and better insulation, and glazing angles that capture more sunlight in winter and reducing it in summer to prevent overheating. This makes these PSGs last much longer ($\geq$ 50 years) and able to withstand extreme weather events (high winds and snow loads), without the expense of fossil energy for heating, cooling and lighting, replacement of Polyethylene (PE) covers every 4-6 years, whose prices producers cannot control but which have a major impact on profitability.

The simplest way to think about the choice is this:

A Passive Solar Greenhouse is an investment for a lifetime
whereas a conventional greenhouse is an ever-increasing expense.

The SunCatcher Passive Solar Greenhouse

Whether or not you are concerned by climate change, farmers and ranchers whose livelihoods are directly dependent on weather and climate are already experiencing its effects, indirectly affecting consumers through higher prices and supply issues. The SunCatcher team believes that we, as individuals, families and communities, should spend our time and efforts working to implement solutions available to us all RIGHT NOW!!!

SunCatcher Greenhouse has spent the last 25 years researching, building and refining free standing passive solar greenhouses in the Southern Appalachian Mountains. Out of that work came the first patented freestanding passive solar greenhouse in the United States (US 9554523 B2). It is designed to handle real winters, real wind, real snow loads, and do it without grid-electricity or fossil fuel, neither of which is guaranteed to be available during extreme weather events.

SunCatcher stands on the shoulders of the people who pioneered passive solar design in the 1970's and 80's, which consisted of modifications or attached structures aimed at heating homes or other buildings using just the energy of the sun (Balcombe, 1987). Their early structures and books were a remarkable start but an industry that should have followed never really did, partly because energy got cheap again, partly because of politics, and partly because some of those early designs had real flaws that put people off. SunCatcher CEO Dr. Terry Carroll lived in the Four Corners Region during the heyday of that work, and was able to experience and learned firsthand about the passive solar design work of the time!

Fifty years on, building materials and technologies have evolved and are considerably better. Glazing, insulation, computer automation, photovoltaics and structural insulated panels have given us design and building options unavailable at that time. In this book, you will see how those advances have been applied to specific design choices in a SunCatcher, using photographs of the building of the Hawk's Nest SunCatcher as a working illustration.

If you have read other passive solar greenhouse texts, you may find some of the information here familiar. But you will also see modifications to previous designs as well as brand-new design concepts. While we will be taking a fresh look at passive solar greenhouse design, we will also refer you to the work of the early PSG pioneers which has benefitted our work and thought in developing the SunCatcher PSG; we will point these out by listing specific "further readings" at the end of several chapters.

What the book covers

The scope of this book is deliberately narrow, and examines one proven, patented free-standing PSG design in depth: The SunCatcher PSG. We take this single design apart and explain the

scientific principles behind each component using diagrams, photographs, data from experimental builds, and real and hypothetical performance graphs to show how the physics drives the design and how the design behaves in operation. What we share with you is research and science based; while the engineering can be applied to different designs, the physics is not going to change from one design to the other. While not working with and collecting extensive data on other applications and designs, we believe the information we share in this book can be adapted and applied to other season-extension structures such as traditional glass, hoop, earth berm, attached, and pit greenhouses. We are simply most confident about the design we have developed and tested.

A few subjects are deliberately outside the scope of this book:

Aquaponics and hydroponics are popular methods in modern greenhouse operations, but we have concerns about the large amount of moisture (and heat) released from open water containers in a closed space. We have not done enough work with them to give confident guidance. There is a need for additional research and development on ways to deal with high humidity levels using hydro-/aquaponics, especially in greenhouses using a Ground-Air Heat Transfer (GAHT) system for heating and cooling.

What to grow and how to grow it. Raised beds versus in-soil versus pots, organic versus conventional methods, crop and variety selection, fertilization and watering methods, ... are decisions for individual growers shaped by climate, market, personal taste. Plenty of good books cover that ground; a short reading list is provided in Appendix 6.

How the book is organized

This book approaches the topic differently than other texts. Rather than the usual linear learning model, we use a "spiral" learning approach where we introduce various concepts then revisit them several times in more detail for various applications and situations. The seeming redundancy (spiral) will help the reader to achieve understanding in more depth, while trying not to overwhelm. The manual looks at the ‘what’ and ‘why’ for each design feature by explaining the underlying science principles and concepts then integrating those single concepts into systems. Understanding these principles and concepts enables you to modify your design to meet your needs as appropriate. Hopefully you will have many "Ah-hah" moments as you begin to see all the interconnections in the design and ways to apply them.

Chapters I through IV will discuss the history of greenhouse design, introduce Passive Solar Greenhouses and the science principles behind their design; and, lastly, provide an overview of the design of and experiences with experimental PSGs we have worked with over a 25-year period that provided clues and insights on design, materials and thermal performance.

Chapters V through X go into more detail of the physics governing the SunCatcher design. We have tried to use simple language and to be as brief as possible to explain the science, but one cannot avoid all science terminology and units. A glossary of science terms is provided in a Glossary in Appendix 1.

A passive solar greenhouse depends entirely on the sun for light ànd heat. In Chapter V, we provide the reader with a basic understanding of how the Sun moves across the sky, and how the seasons influence sunlight. Chapter VI provides basic information on weather and climate as these affect the performance of a PSG throughout the year. Chapter VII goes into more detail on (sun)light: Its angle throughout the year and how that affects PSG performance in different seasons. This is followed in Chapter VIII with a review of glazing materials and their effect on the quantity and quality of sunlight admitted into a PSG.

As the Sun doesn't shine 24 hours a day, storing heat energy in thermal mass for the use at night, on cloudy days but especially during the short winter days is what makes a PSG work. Chapter VIII explains how you can use just the Sun for heating a PSG in the winter. The amount, type and performance of different types of thermal mass is the subject of Chapter IX. Finally, in Chapter X, air, air management and ventilation are discussed as they are key in managing the interior climate of a PSG.

The next seven chapters provide information on how to build your own SunCatcher greenhouse. Chapter XI is an introduction of where and how to begin your project. For a SunCatcher to perform as intended, selecting a good site is of prime importance. Chapter XII provides an overview of different approaches and tools available to find the best site on your property. We will explain the importance of the general East-West orientation to capture the most sunlight during the winter period, as well slight deviations to this orientation to capture sunlight earlier or later in the day.

How the physics principles that determine the performance of a SunCatcher translate into its design is the subject of Chapter XIII. The relationship between length, width, and, height of the SunCatcher; the placement of the lower, upper and back vents, and size (aperture) and angle of the glazing allowing the structure to catch as much sunlight as possible in winter, and reflect it in summer.

Chapter XIV discusses the importance of conserving the sun’s energy (heat) to maintain adequate growing conditions year-round by ensuring to plug leaks with a tight, well-insulated structure. We explain the importance of strictly adhering to the basic architecture and building requirements to ensure performance. Chapter XV provides an overview of individual choices builders can make such as the type of flooring, glazing, interior/exterior colors as well as optional items, such as electrical decisions (grid or solar), automation of vents, fans, lights, and watering, and monitoring of weather and interior climate (dashboard, internet connection, ...).

Chapter XVI provides information on how to manage and operate a PSG, as it is different from operating standard greenhouses. We will not go into depth on what to grow and how in your SunCatcher, these are individual farmer decisions based on their experience, method (organic or not; raised beds, in-ground, or in pots), and local market demand. For individuals interesting in growing their food year-round in a SunCatcher PSG, what to grow will most likely be determined by what they like to eat.

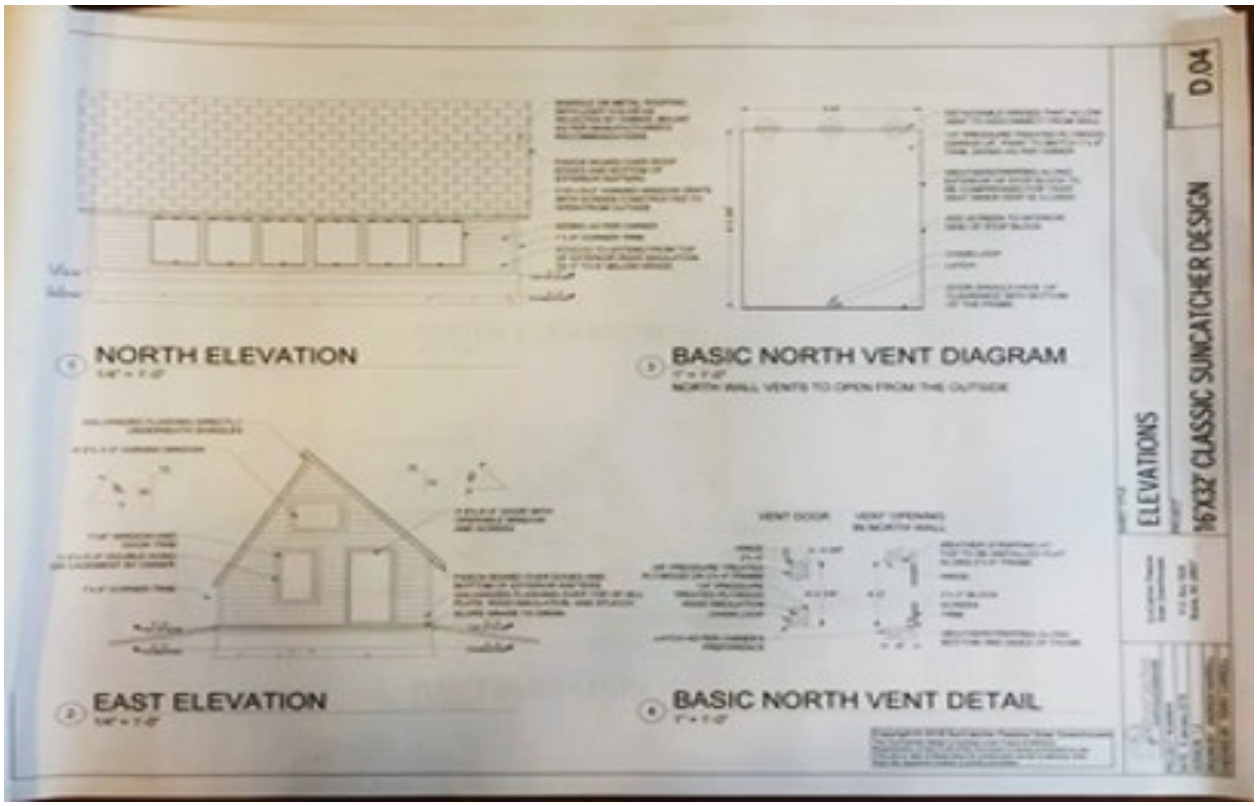
After your PSG is built, there is of course still work to do to restore the area around the

greenhouse. Chapter XVII provides tips and ideas for landscaping, in particular dealing with drainage and wind.

Finally, in Chapter XVIII, we use the construction of the Hawk's Nest SunCatcher to show you the construction process, providing illustrations for do's and don'ts, especially pointing to key things to pay attention to [NOTE: this chapter is still being written].

There is a lot going on here, don't let the seeming simplicity fool you!!! We suggest you read the book several times as there are several complex systems designed to work in unison. Study the science section first so you are comfortable with that. Understanding the science behind the design will help you understand the concepts as they are introduced and integrated into the overall design. The concepts will make more sense as you go through the design process.
To make the greenhouse design itself as simple as possible (more durable with less to go wrong), we used a somewhat unique problem-solving approach for designing any "passive system". Working through new problems, we would first explore ways to reduce the overall system to solve the problem (without creating other problems). If that didn't work, we explored ways to rearrange the parts of the existing system; if that didn't work, then and only then would we add some new component to the system. This simplification process also reduces the energy needed to improve the system (Second Law of Thermodynamics)!

For those ready to take the leap, you can obtain blueprints from SunCatcher.



Our hope is this text (and others) will help to grow and share the body of knowledge about Passive Solar Greenhouse Design. This is intended to be an organic and expanding “work-in-progress” with on-going review and input from readers and growers. We see this as possibly the first of several editions, each including the latest input and evolving in form and interactiveness.

Let us hear from you. We all need your feedback!

References

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Acknowledgements

To be written