Types of Solar

Greenhouse (Solar Photosynthesis)

A greenhouse (also called a glasshouse)**,** is a building designed for the production of fruits, vegetables, flowers, and plants that require special conditions or temperature. This structure protects out-of-season or tender plants against excessive cold or heat.

A greenhouse has a large expanse of glazing (glass, polyethylene, polyvinyl, or fiberglass) on its sides and roof. Plants are exposed to natural light for much of the day and utilize photosynthesis to grow.

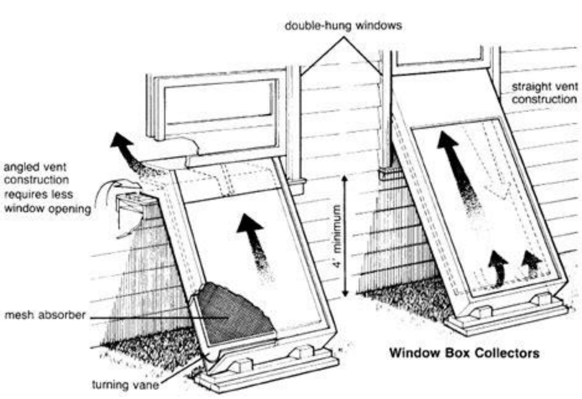
The greenhouse is also heated by the thermal energy of sunlight captured inside the building. Modern designs stabilize temperature naturally using thermal mass of various means (earth contact, water-filled black barrels, or rocket mass heaters). Also, supplemental heat and light can be used to extend the plants growing season.

Because a greenhouse can also become too hot, a ventilating system is needed to help maintain temperature.

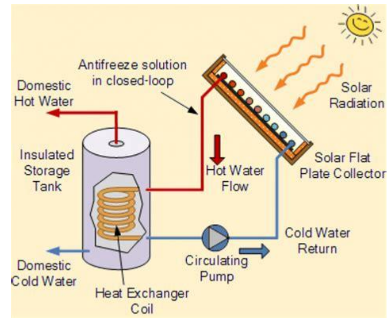
Solar Air & Solar Water Heating (Solar Thermal)

Solar Thermal heating systems use the concentrated thermal energy of sunlight to heat air, water or a mass. Think about how hot pavement can get in the summer. Solar Thermal systems can direct this heat to be stored or utilized within a building or structure. Typically, heated air is used and heated water is stored.

Passive solar systems rely on the structure of the building to collect or reject heat. Large south-facing windows or collectors, capture thermal energy from the winter sun that has a lower passage in the sky. During the Summer, a roof overhang can block the collection of excessive heat from the sun. (https://www.builditsolar.com/Experimental/PEXColDHW/Overview.htm)



Solar Water heating uses water-filled collectors to transfer thermal energy to be stored or used.



Active solar heating systems use heat pumps to transfer the collected heat from solar collectors into the building for storage or use.

Normally these thermal systems are not designed as stand-alone systems, but are complimentary to other existing heating systems. (https://www.sciencedirect.com/topics/engineering/solar-heating-system)

Solar Panels (Solar Photovoltaic)

Instead of using the thermal energy of sunlight, solar photovoltaic panels (Solar PV) turn sunlight's photon stream into direct current (DC) electricity. This can be stored into batteries and converted to alternating current (AC) for use. The size of the Solar PV system can be scaled from powering a small portable "Solar Generator" to providing some of the power for a large airport.

Solar PV systems are classified two ways: *On-Grid* and *Off-Grid*.

On-grid (or grid-tied) PV systems primarily use their generated electricity to offset the cost of the power supplied by the national electrical grid. This "net-metering" is where the building owner sells power back to the local power company. Because of safety issues to linemen, if the grid-power goes off, then the solar PV system will shutdown to prevent backflow of electricity to the broken electrical grid. This means your lights and appliances will shut off when the electric power goes off, even if there is sunlight available for power.

A hybrid grid-tied PV system can add batteries, so if the grid power goes down, then specific circuits at the building can continue to run off the batteries. This power is prevented from backflowing into the broken grid.

Off-grid means the Solar PV System is completely disconnected from the nationwide electrical grid. Typically, these off-grid systems rely on batteries and supplemental power from a generator, hydro-electric, or wind when there is not enough sunlight to produce electricity. This means that you are responsible to manage your own equipment and power budget. It also means you are not dependent on the local power company.

Why do I want Solar?

Most people want Solar for financial or independence reasons, rather than going "green". Energy prices are continuing to increase and we worry that our personal income can't keep up with utility bills. Even with this pressure we still want to keep our modern lifestyle and conveniences: Refrigerators, Stoves, Washers, Dryers, Air Conditioning, Furnace, Computers, Televisions, etc.

Instead of being totally dependent on outside energy systems, we can take some responsibility to change our situation. We can gain independence with some lifestyle changes and by incorporating our own energy systems. While we are focusing on Solar PV here, there is also Hydroelectric, Wind, and Generator electrical sources that could be integrated to provide some, or even all of your family's energy needs.

There are many people that are choosing to go "Off-Grid", by building a new home far from the electric utility, by simply wanting to reduce their consumption, or by determining they don't want to be energy dependent in case of bad weather or civil unrest.

Maybe you just want some power in a shed for lights and charging a mobile device?

All of these are valid reasons. So, keep these in mind, because these reasons shape our Plan, Budget, Effort, and Timeframe.

Action: Write these reasons down to clarify your thoughts and feelings.

Analyzing our Habits

In our patterns of life, we build and maintain a certain way of living. We live in a fast-paced world where we find that we live quite differently than how our grandparents did. If we didn't have these modern conveniences, then we would find that there isn't enough time in the day to live like them.

The reality – It's expensive to totally replace all your current energy needs. So, you will need to take a truthful look at your life activities to determine your energy situation.

For each life activity:

Does this activity have an energy "need" or is it just an energy "want"?
Can we reduce this activities energy usage?
Can we substitute with another energy source?
Can we eliminate the energy needed?
When can schedule this energy usage? (Especially in an Off-Grid home)

For most families, you will need to understand and set some energy limitations. Only you can determine this for yourself. If you are unsure about some activity, then revisit your reasons for "Why do I want Solar?"

Action: Write down your home activities, then for each, write down answers to these questions.

Analyzing our Habitat (Energy Audit)

Our homes use energy based on our habits. Having long hot showers or leaving a window in the summer with your A/C on, will use much more energy than other habits or behaviors.

We want know how much energy your home uses (on average) over the past year. Once you get this baseline established then you can make better choices about your habits and the size of the solar array needed.

A Home Energy Audit goes further and will also look at how your home uses energy.

- How energy efficient are your windows and doors?
- Do you have drafts in your house?
- Is your furnace and A/C older and are they inefficient? Are your filters clean?
- How much insulation does your attic and walls have?
- Do you turn your hot water heater up or down based on the season?
- Does your hot water heater and hot water lines have adequate insulation?
- Do you have timers or motion sensors for lights?
- Do you have occupancy sensors that control temperature and lights?

Home Energy Use (rough averages) (from https://www.greenlogic.com and other)

1. Space Heating 45%
2. Water Heating 15%
3. Appliances 13%
4. Lighting 9%
5. Washer and Dryer 5%
6. Television and Media 4%
7. Phantom Power Loss

You can hire a contractor with some specialized tools to make precise measurements, or you can do decent job yourself, creating a Home Energy Audit.

There are worksheets available to get you started.

Action: Create the best Home Energy Audit you can.

Pro Tip: Putting money in an Audit, will save you money and headaches later.

Analyzing our Habitat (Environment)

We also need to look at our homes and evaluate what energy sources are available to us.

- Will we be off-grid?
- Do we have a South-facing yard or roof for a Solar PV Array or Solar Thermal system?
- Do we have tall trees blocking the sun to our yard or house? Do the leaves fall in Winter?
- Do we have adequate and consistent wind for a micro-turbine?
- Do we have access to a year-round stream with adequate waterflow for a hydroelectric generator?
- Are we connected to natural gas or have a propane tank?
- Does the electrical utility have surge pricing? When is that? How much extra cost?

Many of these various energy systems can be combined more easily now using modern inverters and batteries. These systems can either reduce our draw from the electric utility or they can supply enough power to cover our needs and sell some back to the power company.

Action: Create a map, then identify and describe your environment.

Finding Patterns for our Plan and Design

Looking at our Habits and Habitats, patterns will emerge. We use these patterns to build our Plan and Design.

Patterns:

- We have tall trees that shade our house in the Summer, do we have a sunny area in our yard for Solar?
- During the Fall and Winter, we get a consistent cold Northern wind. What trees can we plant to block that wind away from our house? Can we use that to power a wind turbine?
- On-grid: Shifting your heavy electrical use to nights, selling excess power during surge pricing times.
- Off-grid: Shifting your heavy electrical use to days, when your system generates the most power.

***Action: Write down all the patterns you can identify and quantify*. If you don't have actual measurements, then there are resources available to give you estimates.**

Pro Tip: It's much cheaper to change your Plans and Design, than to change your Build.

Design

The Plan is what we want to do. The Design is what we can do.

(Section to be worked on)

Build

You may need qualified electricians for all or parts of your build.   You may need permits and inspections.

Pro Tip: What is more expensive than a solar system? Having no power available (Steven Harris)

(Section to be worked on)

Analyze – Habits, Routines, Structures, and Environment

- Find what Energy can be eliminated, reduced or cannot change. The energy audit helps you identify potential problems that can be solved before jumping into a huge transformation.
- Do any items (appliances, fixtures, etc.) need fixed or maintained to use less energy?
- Can we change an item slightly to use less energy? (Hot water heater on a timer)
- Can we supplement an appliance? (Use a fireplace in addition to furnace; Wear a sweater)
- Can we add to an item to make it better? (More insulation in the attic)
- Can we remove an appliance? (Cut all vegetables with knife; No food processor)
- Can we plant or remove trees to help with heating or cooling?
- Can we create strategic house shading using vine supporting trellis?

Pro Tip: Every dollar spent on reducing energy usage, will save several dollars spent on buying a larger solar system.

Plan – What are we designing for?

- Existing Structures – e.g., House, Outbuildings, Chickencoops.
  - Available roof or yard space dictates how much solar you can generate.

- What Kind of Connection?
  - On-Grid – A grid-tied system that doesn't require batteries
    - Lowest initial cost, simplest design, most efficent
  - Off-Grid – No connection to Electrical Grid.
    - Typically requires battery systems.
    - Power is independent of the Electrical Grid and Electric company
  - Hybrid – Can run either On or Off-Grid.
    - Batteries optional
  - Retrofit – Add more Solar capacity or off-grid capability (using AC coupling) with a 2nd Inverter

- Capacity
  - Question 1 - What percentage are we Supplementing?
  - Question 2 – What is your highest electric bill? February or August from last two years.
    - How much capacity or Load do we need?
    - For Off-Grid, you need to determine a power budget.
  - Size of System = (KWH/30) * 4.6 * Power Factor * Supplementing Fraction
    - KWH – Kilowatt hours used per month. Look on your February or August electric bill as these months use the most energy
    - 4.6 - Hours of Sunlight avg a day in KC metro Area
    - PF – Power factor of inverter being used (generally 80%)
    - Percent of power we are supplementing. Expressed as a fraction. (50% = .5)
  - Panel wattage is under ideal conditions. Expect 80% of watts in real world.
  - Solar panels lose 0.7% power yearly becoming 80% effective at the end of their 25-year lifespan

- Location and size of the PV Panels
  - Use Existing Structure? – Pitched Roof or Flat roof
  - Use New Structure? – Standalone, Multiuse, Ground Mount, or Pole Mount
  - Shadows and Obstructions – Work around, eliminate, or rearrange
  - Solar panel sizes approx. 65x39 305w - 66x40 380w
  - Consider latitude, direction, and tilt. Position for maximizing energy for Location and season.
    - KC Metro Latitude 39 degrees design for maximum overall power
    - Spring/Fall 51 sun angle optimum angle for year-long production
    - Summer 74 Sun angle optimum angle for summer production
    - Winter 28 sun angle optimum angle for winter production
  - Roof Measurements
    - Available area = Width (minus 4' at each side of roof) X Length (minus 2' from peak)
    - Obstructions (can we move panel one side or another? Big shadow? Cut tree down?
    - Direction (Facing) – South best, West second, and East third. No North!
    - Angle loss – South 0% loss, SSSW 5% loss, SW 10% loss, SWWW 15% loss, W 20% loss. Eastward is similar.
    - Angle every 10 degrees is 1% loss then +3 then +6 then +12

    - Example of existing structure. My garage.
      - Measurement of roof - 162" W x 466" L @ 17 degrees facing South East 75,492" squared
      - Solar panels installed 65"x 39" x 27 panels 68,445" squared
      - 90% space used with 1 obstruction

  - Requires Rail clamps, strut, and mountings to attach to building or structure
  - Grounding is needed - Add a ground rod for this and tie to existing grounds using AWG #4

- Inverters
  - Convert DC power from the panels to be useable inside the house AC electrical system
  - Brains of the Alternative Energy System
  - Various kinds of inverters, choose features that fit your application
  - Newer ones have many more features and efficiency
  - Can have multiple DC inputs (Solar, Battery, Wind, Hydroelectric) and an AC input (Generator)
  - Typically incorporates a battery monitor and charger
  - Either MPPT (Maximum Power Point Tracking) or PWM (Pulse Width Modulation)
    - Prefer MPPT over PWM in larger systems
    - Prefer MPPT where you need maximum efficiency, especially where you have shadows over panels or limited daylight
    - Prefer PWM for smaller (<2 KW), simpler, and budget standalone systems
  - If you are using Mechanical generated energy as an input, you will need a dump output
    - Used after batteries are filled and you still have excess energy
    - DC Hot water heater element?
    - Heat a greenhouse
    - Pump water up the hill into a reservoir
  - Float or Bond the System?

- Batteries
    - Allows for Hybrid and Off-Grid Designs
    - Will be expensive to purchase and typically increases your ROI time
    - Various costs, safety, charging profiles, and lifespan
    - Can be added to system after initial build
    - Heavy and typically need a protective room-temperature environment
    - Some types are more easily maintainable and some are repairable
    - Types
        - Lead Acid – Deep Cycle, AGM, Gel, OPzV
            - Plan for 50% depth of discharge
        - Nickel Cadmium (NiCad)
        - Lithium Ion – LiFePo4, LTO
        - Flow
        - Nickle Iron
        - Sodium Nickel Chloride
        - Hydrogen
        - Pumped Hydro Storage
            - Uses excess energy to pump water uphill to a reservoir for later use
    - Voltages (12/24/48 volts)
        - Higher voltages (lowers amperage) allow for smaller connecting wires
            - Still need to size right for safety
            - Less expensive
            - Easier to work with
    - Amperage-Hours
        - Use this to compare two batteries capacities
        - Will need to convert KWh to Ah to determine needed capacity

- Connection Pieces
    - Wires – Electrically connect devices using insulated coated copper string
    - Combiner boxes – Combines Strings of Panels into Arrays
    - Fuses – Replaceable devices that are made to self-destruct before your wire melts
    - Disconnects – Manual switches that break an electrical connection
    - Breakers – Automatic switches that disconnect before your wire melts

- Limited Budget?
    - Consider Micro Inverters.
        - Can add one at a time
        - Some limitations going this grid-tied approach.
        - No batteries or Off-Grid capability
    - Consider designing whole system but purchasing and installing system in phases
        - You may not get all rebates or credits available
        - There is a minimal system expense that must be met for a basic working system.
        - When you have the funds available, then you can add or upgrade components. Can sometimes sell used Solar inverters, or you can repurpose using it in another project.
    - Consider Good, Better, Best
        - First, a small portable emergency system
        - Then a larger Off-grid or Hybrid system to only power freezers, etc.
        - Then a full-sized Hybrid system

- What do the Jurisdictions Require or Offer?
    - Evergy and Freestate Co-op Guide to Solar Arrays (applications, inspections)
    - County and City Regulations regarding Solar Arrays (inspections, permits)
    - National Electrical Code Requirements
    - Insurance Companies Stipulations
    - What are stipulations on Jurisdiction Grants, Credits, and Rebates?

- What do the Utilities Require or Offer?
    - Contact the Utility regarding becoming “Generation Station”
    - Generally, the Utility must approve your equipment you buy before installation
    - What are the stipulations on Utility Grants, Credits, and Rebates?
    - Utility Requirements
        - Appropriate Disconnects
        - Preventing Back Feeding

Will any of these affect your Design? YES!

Design – Putting the pieces together on paper

What systems will we be integrating?

- Are we going with Grid Tie, Off Grid, hybrid or a Mix of Inverters?
- Any Battery Backup Systems, Wind Turbine, Micro Hydroelectric, Emergency or Co-Generators?
- Are we retrofitting an existing grid-tied system with a 2nd system (AC coupling) so we can trick the primary system to turn on when the power grid is down?
- Structures – Existing or New? How are they Facing? What Angle, Shadows, and Obstructions?

- Draw a simple diagram for a grid-tie System, then add in other sources.
- Draw a simple hybrid system for grid-down and add battery backup and generator options
- Draw an AC coupled retrofit of an existing Solar system

Capacity and Efficiency

- Determine the **Load** we are we designing for based on our KWH use, our Space, and our Budget
- Organize your array of panels
    - Put connect strings of panels into series, as to maximize input voltage
        - The higher voltage lets us have longer, smaller wires (less cost)
    - Combine strings to maximize input amperage
    - Inverter might have multiple Solar inputs for adding more panels later

Safety

- Size appropriate Wire, Breakers, Disconnects, Inverters, Combiner Boxes, Panels, and Ground (higher amperages require these to be sized larger)
- Rapid Shutdown

Scheduling work

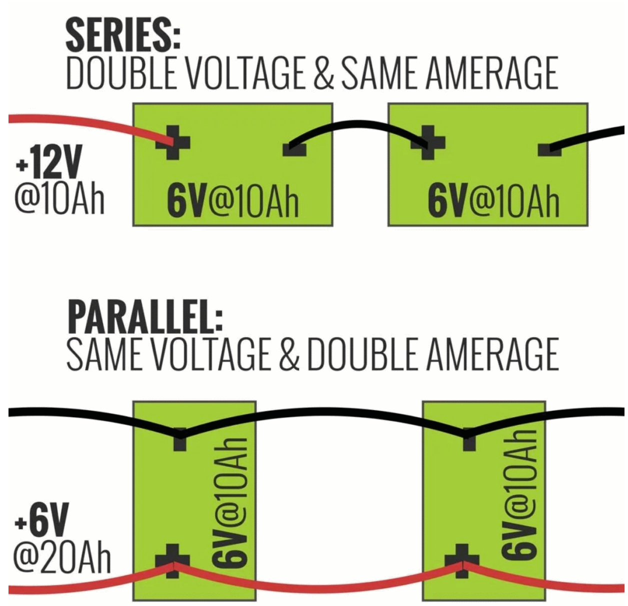
- What permits to pull beforehand?
- What inspections need to be scheduled?

Reference Material

Terminology

Direct Current – A one directional flow of electrical charge (battery power) (Red +, Black -)
Alternating Current – Electrical charge that alternates directions (residential/commercial power)
(Black or Red is hot, White is neutral, Green or Bare is ground)
Watt – A measure of Energy (e.g., 60-watt lamp)
Defined as 1 Watt = 1 Volt x 1 Amp
Watt-Hours = Amount of Energy over Time
(e.g., a 60-watt light on for an hour)
Kilowatt-Hour = 1000 Watt-Hour (KWH) How your electric bill is measured. (Equal to 10 100-watt lights on for an hour)
Volts – The pressure of electrical force
Amperage (Amps) – A volume of electrical current
Amp-Hour – Amount of amperage sustained over time
100Ah = 4amps for 25 hours; 1amps for 100 hours
DOD (Depth of Discharge) – The amount of battery discharge that a battery can handle without excessive shortening of its life. Less DOD will extend battery life.
Lead-Acid 50%; Lithium-Ion 80%

Series – Components that are connected end-to-end forming a single path
Parallel – Components that are connected across each other, forming two paths of common connections



minderresearch.com

Formula

P (Watts) = I (Amps) x V (Volts)

V (Volts) = P (Watts) / I (Amps)

I (Amps) = P (Watts) / V (Volts)

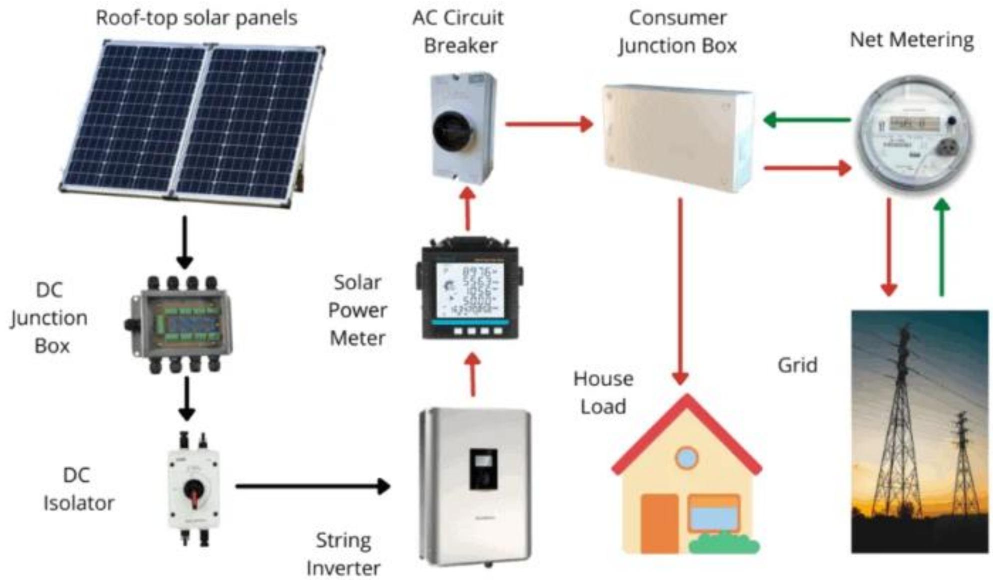
How many Amps is a 60-Watt light? I = P / V
I (Amps) = 60 Watts / 120 Volts = .5 Amps

Convert Watt-Hours to Amp-Hours
Loads are calculated in watt-hours (Wh); batteries in amp-hours (Ah).

Example: How many 48v batteries do we need for a 1.5KW load for 24 hours.
Total Watt-hours = 1,500 watts x 24 hours = 36,000 Wh
Ampere-hours = 36,000 Wh / 48 volts = 750 Ah
Number of 250Ah Lead-Acid batteries (with 50% discharge) = 750 Ah / .50 = 1500 Ah / 250 Ah = 6
Number of 250Ah Lithium Batteries (with 80% DOD) = 750 Ah / .80 = 938 Ah / 250 Ah = 4

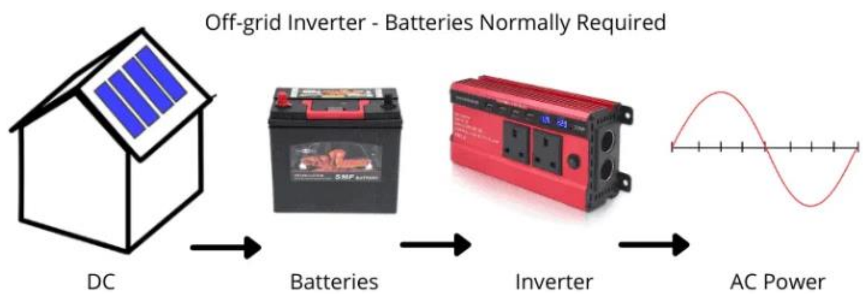
Diagrams

Grid-Tied System



https://diysolarshack.com/

Off-Grid System



https://diysolarshack.com/

Recommended Sites

https://www.builditsolar.com/index.htm