Solar Demonstration Lab

Instructor: Michael Thorburn
Advisor: Samuel Landsberger

TEAM 1: SOLAR PANEL TRACKER - CALVIN CHHUN, MOHAMMED SHUKR, NATHAN CASTRO

TEAM 2: SOLAR HOT WATER - ASHLEY GUO, FAISAL ALDOSSARI, ULISES VEGA PERALTA

TEAM 3: ENERGY ANALYSIS - ALEX RODRIGUEZ, KAILEN LOUALHATI, NAPAT ATIKANIT

TEAM 4: 3D PRINTING - SERGIO MIRANDA, STEVEN GARCIA

Presentation Overview

Mission Statement:

Our goal is to Research, Design, Build, and Demonstrate a solar Photovoltaic system as well as share information about sustainable solar energy with the Cal State Community and the surrounding East LA Community, from schools to community leaders.

Team 1: Solar Panel Tracker

Team 2: Solar Hot Water

Team 3: Energy Analysis

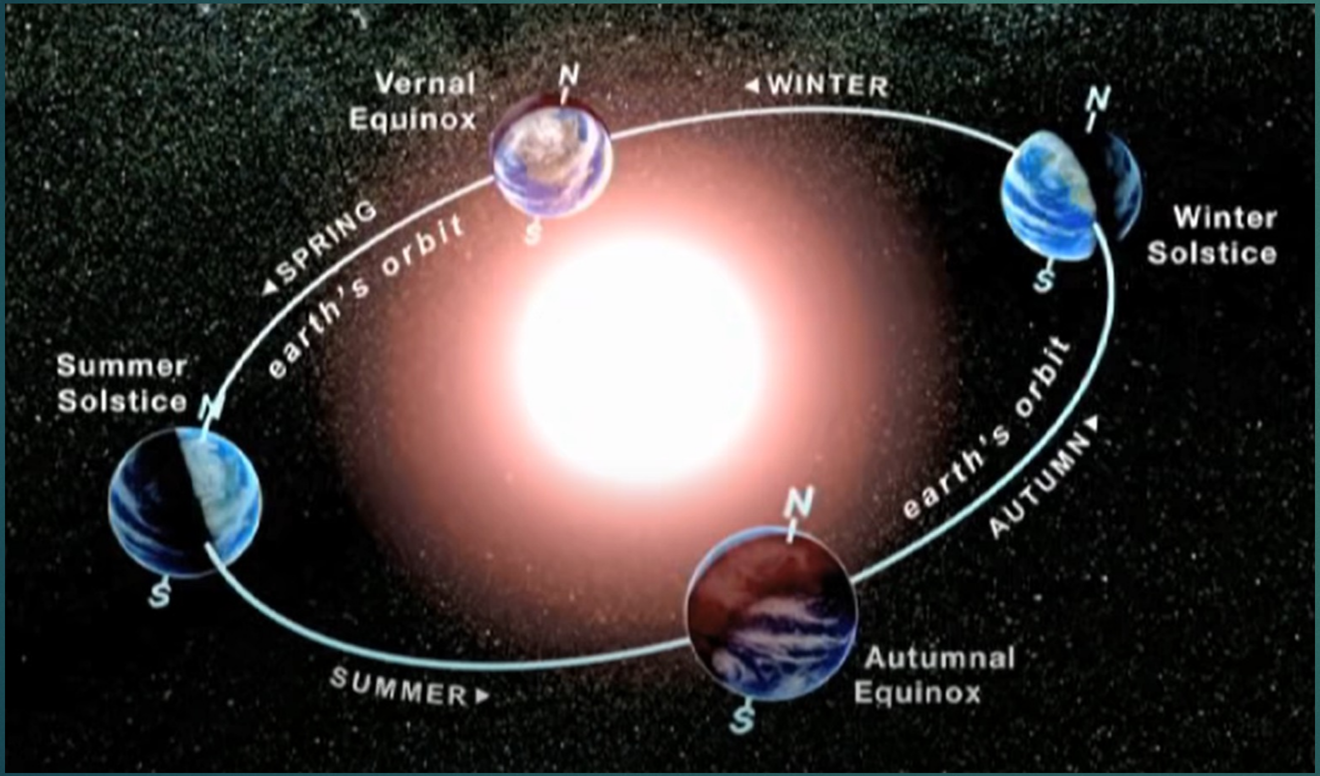
Team 4: 3D Printing

Team 1

Solar Panel Tracker

Calvin, Mohammed, Nathan

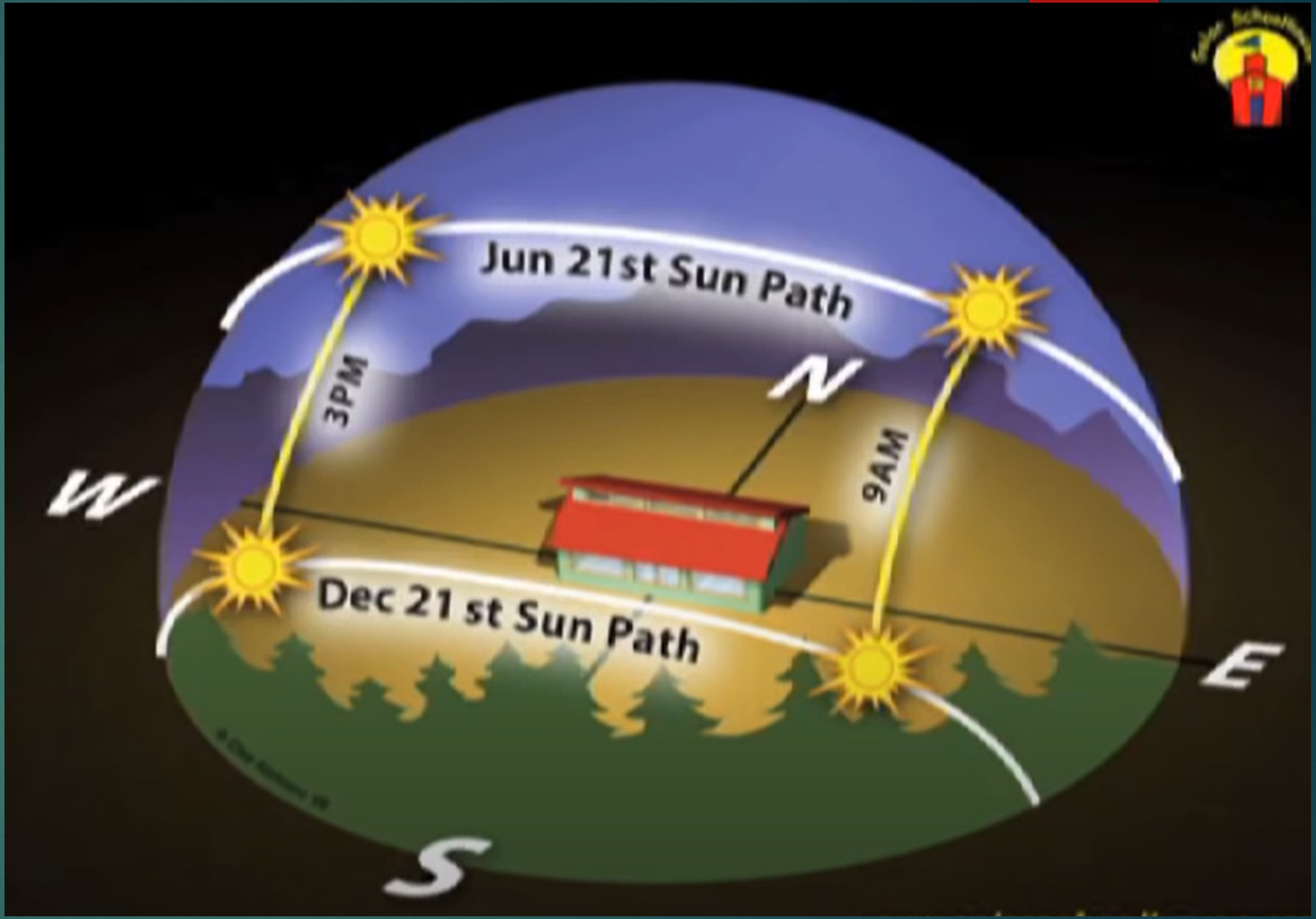
Solar Orientation



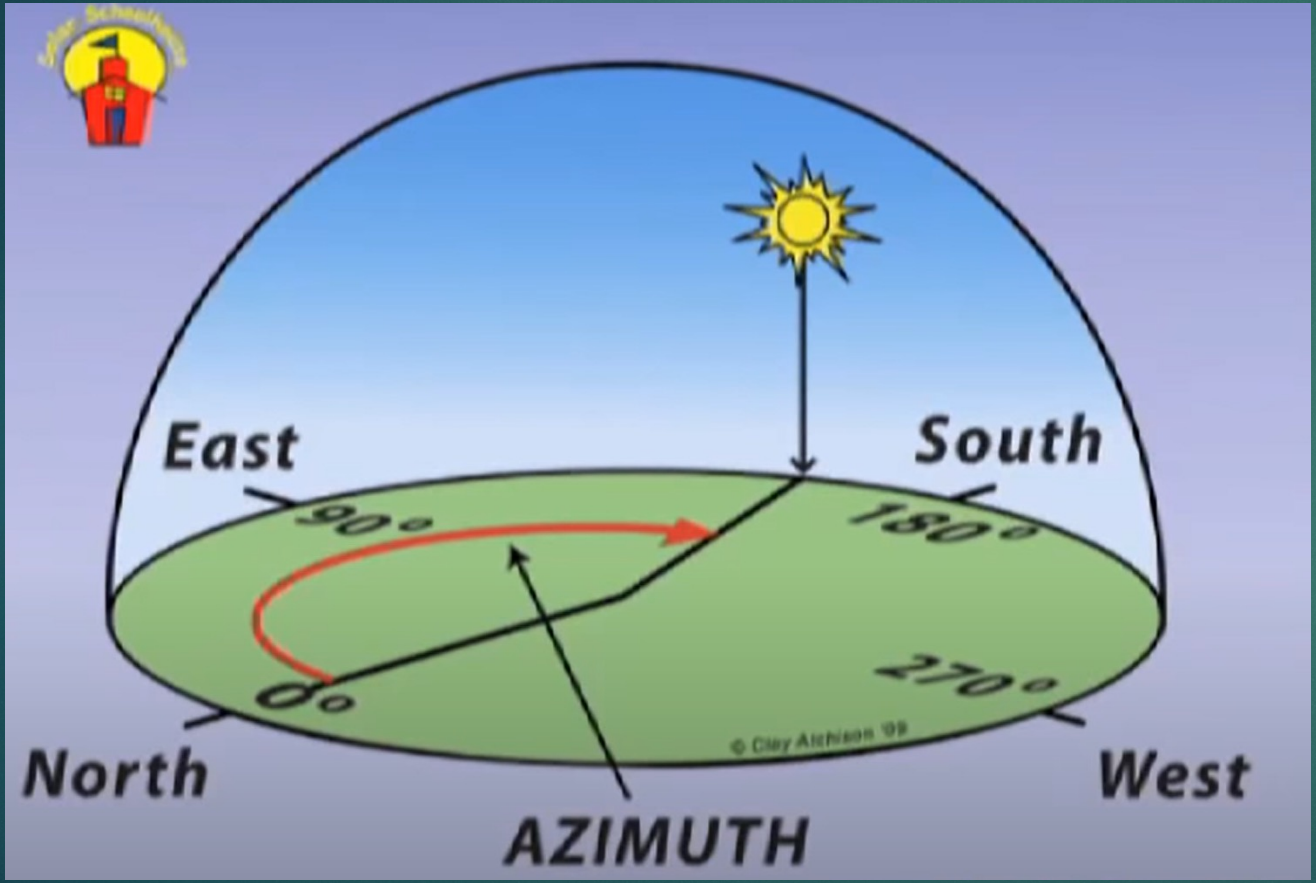
- The Earth's axis is approximately 23.5˚ relative to its orbit around the sun
- For the Northern Hemisphere, the summer solstice is when the Earth's axis is tilted the most towards the sun to the sun
- The vernal and autumnal equinoxes represent the time of year when the Earth's axis is sideways to the sun
- The winter solstice is when the axis is tilted farthest away from the sun

Solar Orientation

- Summer solstice sun path (June 21st) is the longest path
- Winter solstice sun path (Dec 21st) is the shortest path
- Throughout the year the sun's path will always be between the summer solstice path and the winter solstice path

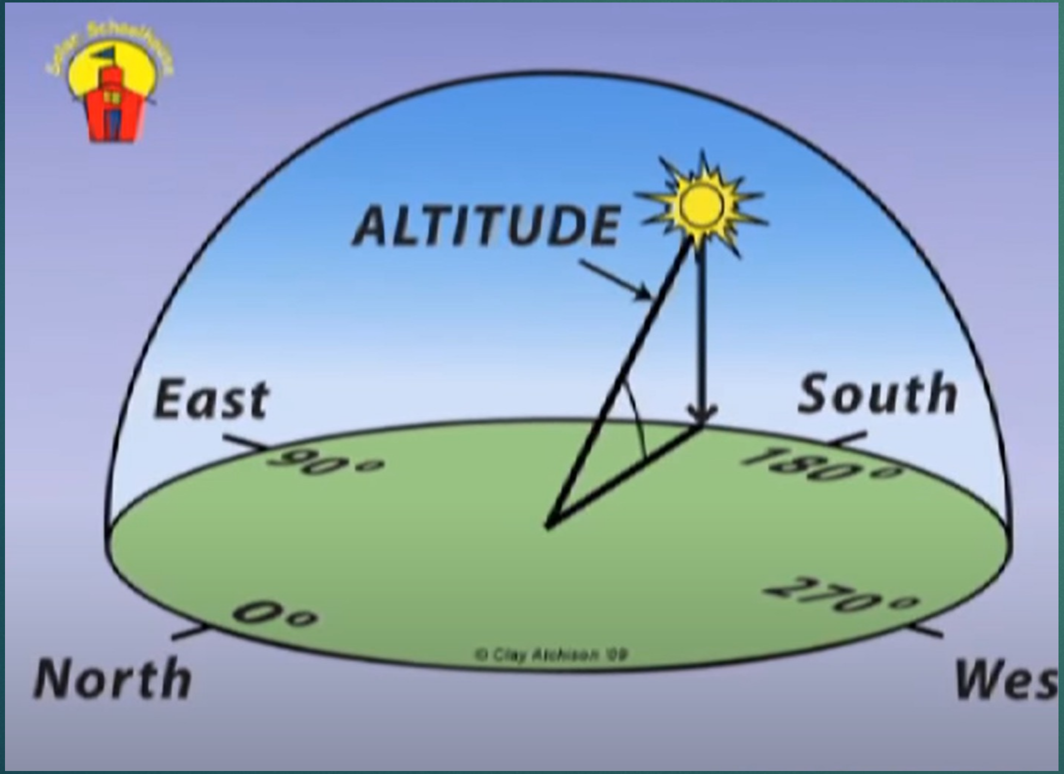


Azimuth



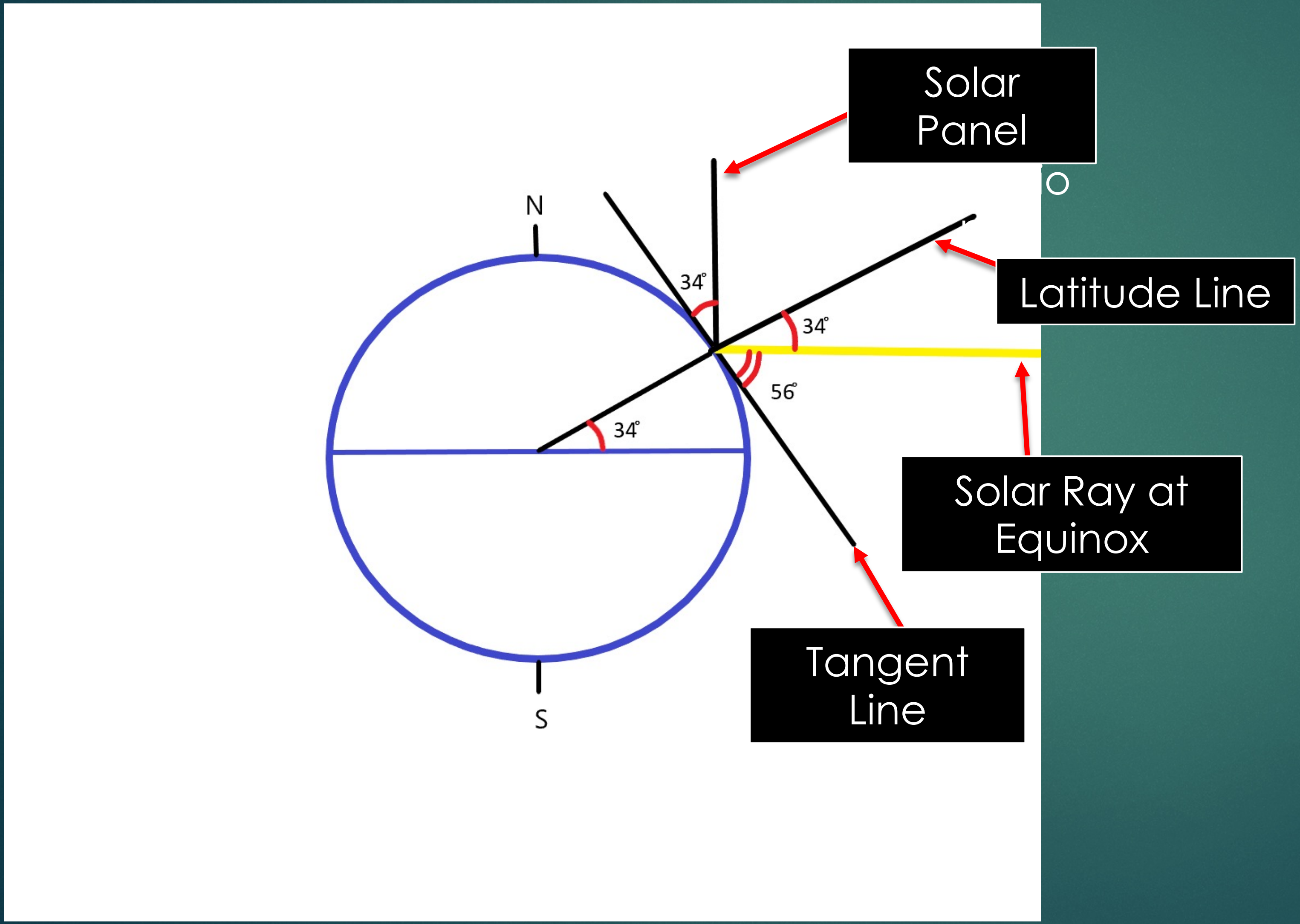
- From a fixed position, the azimuth is the angular measurement that gives the direction or heading of a celestial body
- Where 0˚is true north and 180˚is due south

Altitude (Elevation Angle)



- The altitude of an object is its vertical angular elevation above the horizon
- Sometimes referred to as the elevation angle

Theoretical Calculations



- The latitude for Los Angeles is approximately 34°
- During the equinox the Earth's axis is perpendicular to the direction of sunlight
- The sun's elevation during the equinox will be 56°
- Since the Earth's tilt is 23.5° we get:
  - Summer Solstice Elevation:

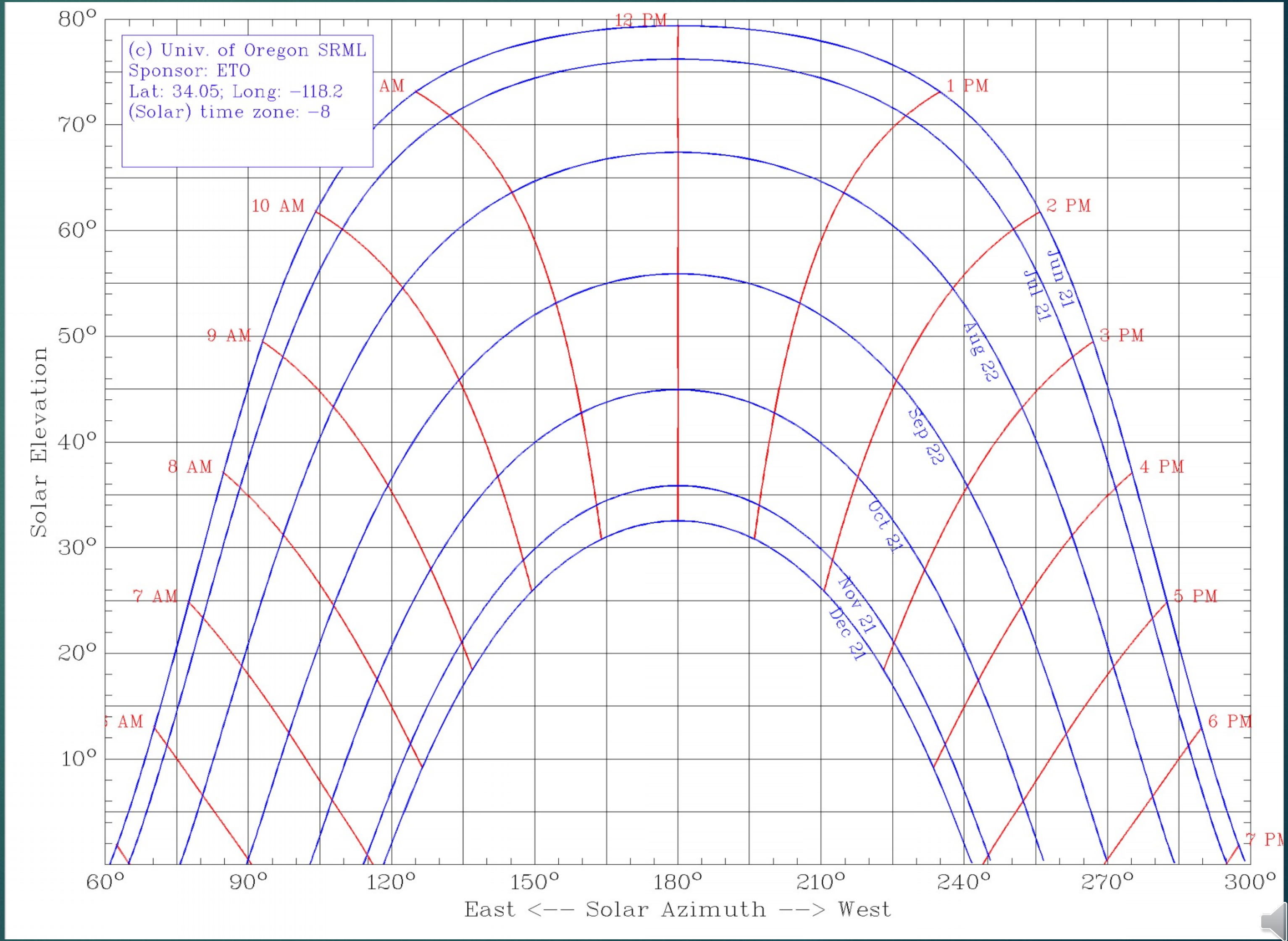
$$Elevation = 56° + 23.5° = 79.5°$$

  - Winter Solstice Elevation:

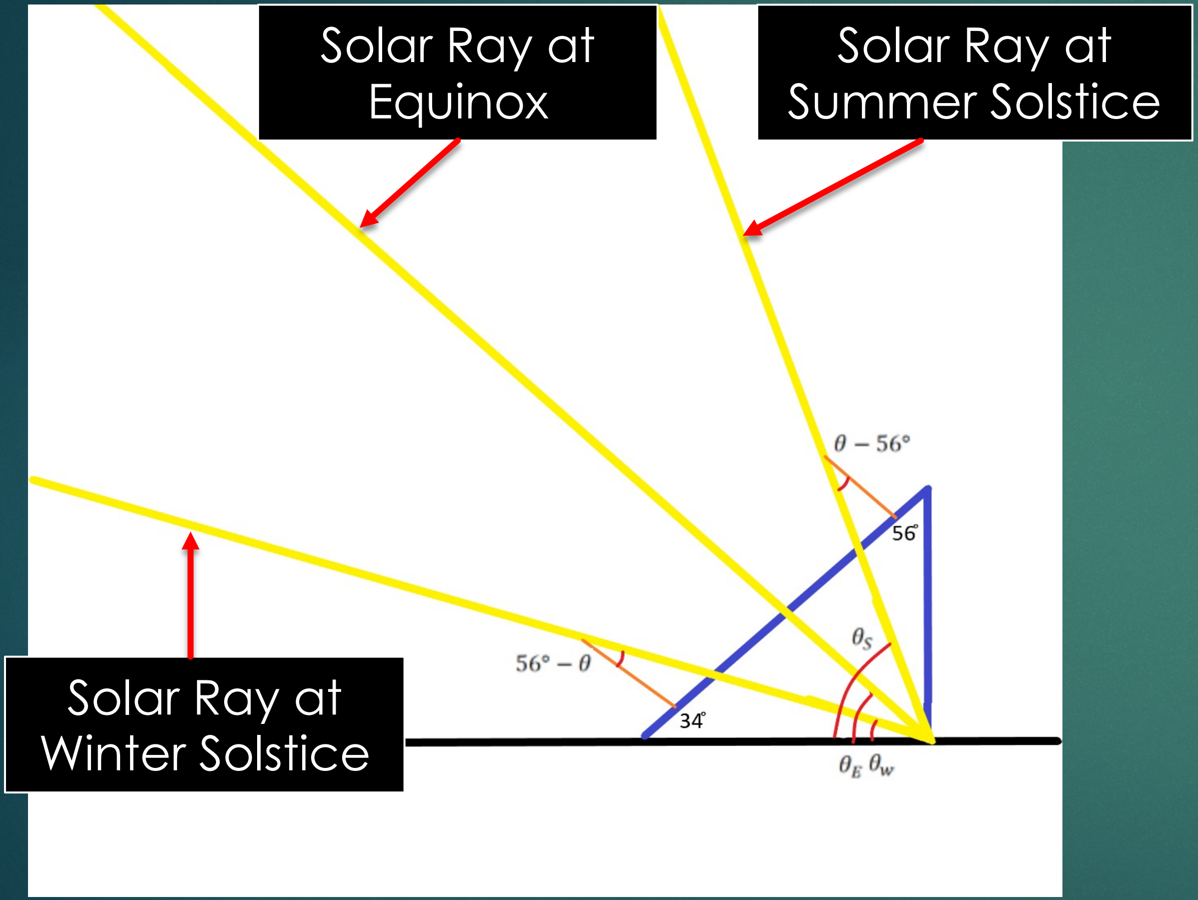
$$Elevation = 56° - 23.5° = 32.5°$$

Solar Chart

- This is the solar chart for latitude 34.05˚, longitude -118.2
- The top blue line represents the summer solstice, at noon the sun's elevation is at 79.5˚as expected
- The bottom blue line represents the winter solstice, at noon the sun's elevation is at 32.5°
- The blue line marked at Sep 22 represents the equinox, at noon the sun's elevation is at 56° as expected



Solar Constant And The Cosine Effect



- Solar panel fixed at 34°
- $Max\ Power = \eta G_{SC} \cos(56° - \theta)\, A$
  - $\eta = panel\ efficiency$
  - $G_{SC} = Solar\ Constant = 1000 \frac{W}{m^2}$
  - $\theta = Solar\ Elevation$
  - $A = Area \approx 0.286\, m^2$
- At summer solstice:

$$P_{max} = \eta \left(1000 \frac{W}{m^2}\right) \cos(56° - 79.5°)\, (0.286\, m^2)$$
$$\approx \eta 263\ W$$

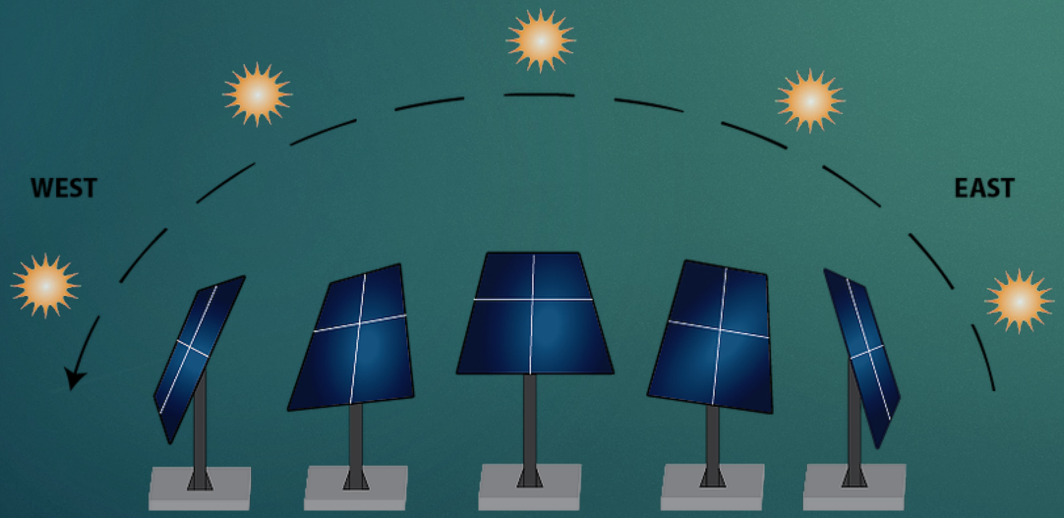
- At winter solstice

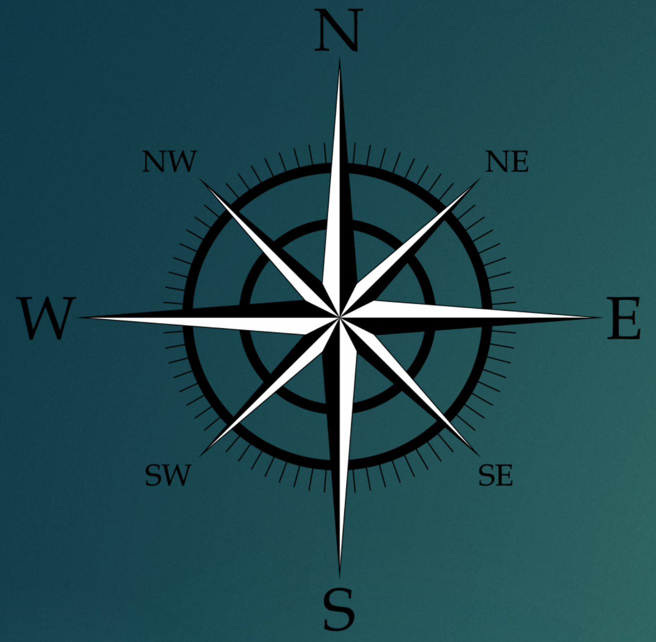
$$P_{max} = \eta \left(1000 \frac{W}{m^2}\right) \cos(56° - 32.5°)\, (0.286\, m^2)$$
$$\approx \eta 263\ W$$

Solar Tracker

Solar tracker is a system that position solar panels at an angle relative to the sun so that they remain perpendicular to sun's ray.

- More sunlight strikes the solar panel
- Less light is reflected
- More energy is absorbed and converted to power





Why Should We Have A Solar Tracking

Advantages - increased energy by about 30 to 40 percent

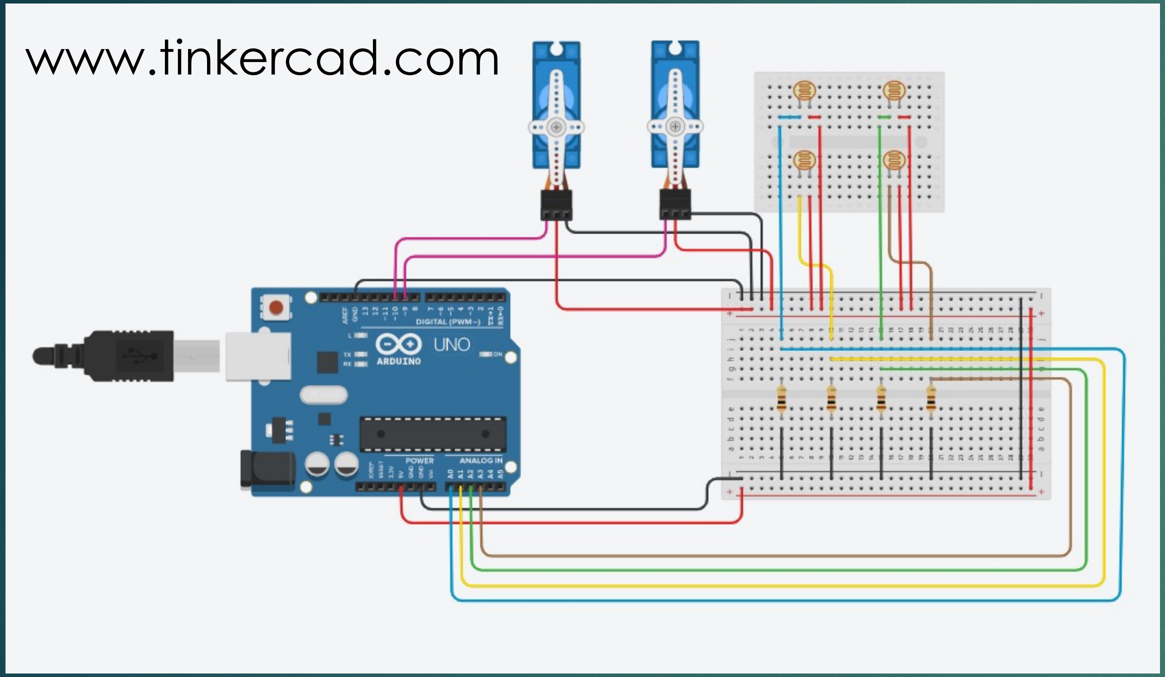
Disadvantages

- Disadvantages:
  - Solar trackers require one or more actuators to move the panel.

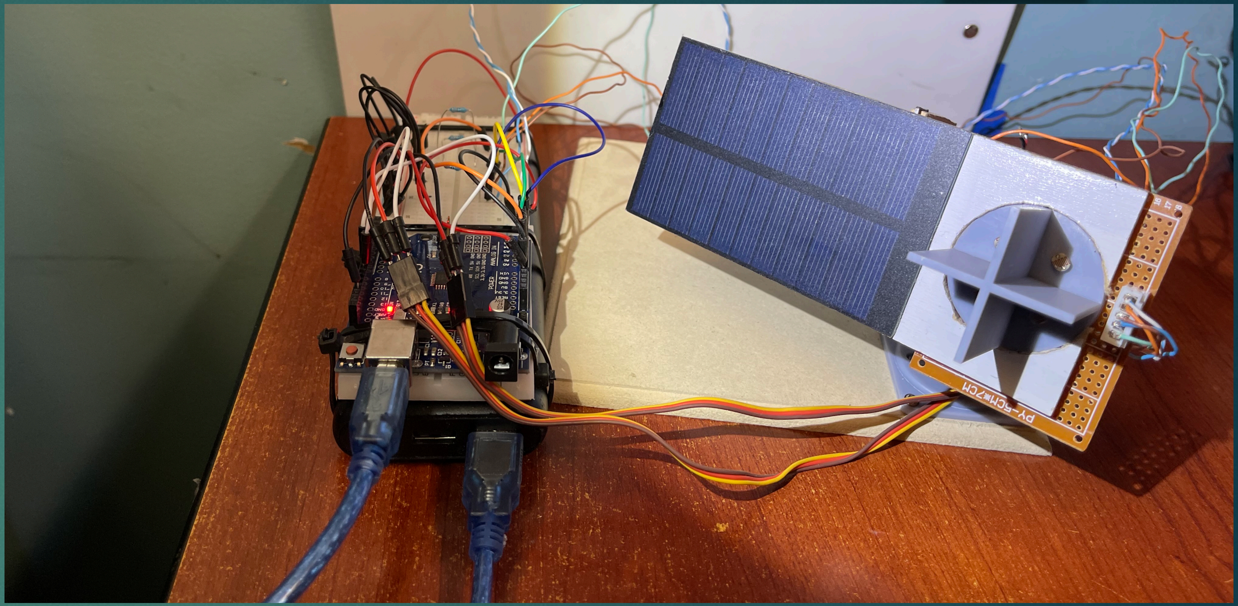
    Increase installation costs

    reduce reliability.
  - Use a small amount of energy.
  - Computer-based solar trackers are more expensive, require additional maintenance, and become obsolete much faster
  - Electronic components parts, may be difficult to replace over time.

Tracking With Arduino



Using tinkercad.com design virtually model and program a mini solar tracking system



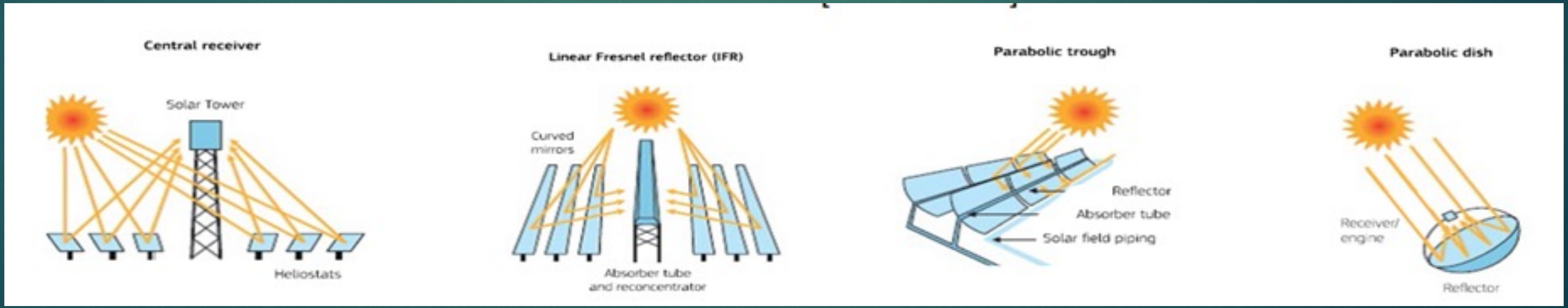
Mini solar tracking prototype plan on using to compare the rate of solar energy production with a fixed solar panel

Solar Concentrated System

- Solar Concentrated System collects the sunlight by using mirrors/ lenses to produce a very high temperature head in order to generate some electricity
- Most of the systems have a heat transfer fluid circulated and heated in the receiver and produce steam
- Solar power system has a tracking system

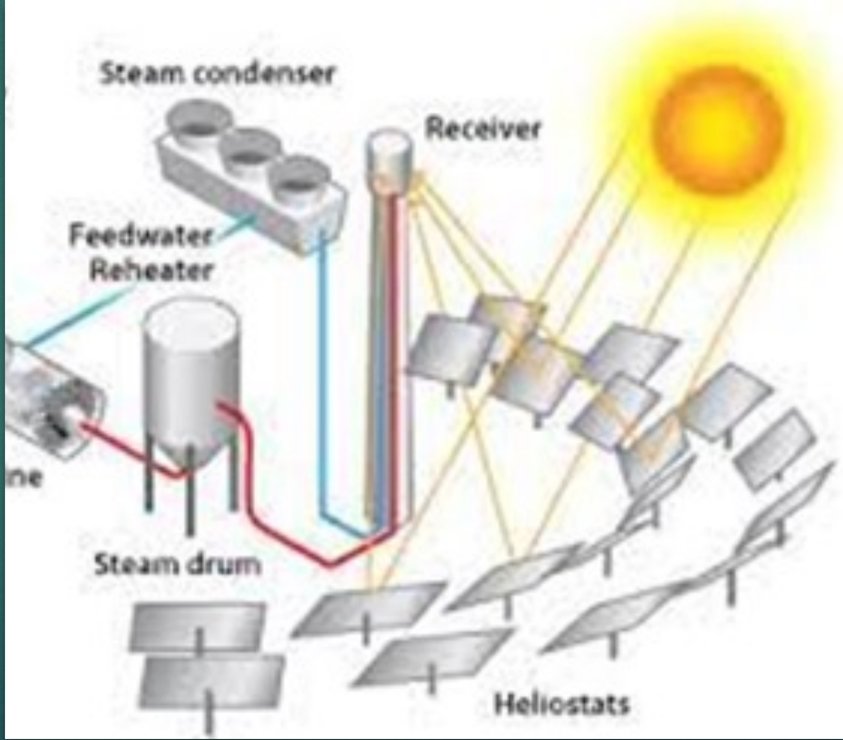
Types of Solar Concentrated System

- Central receiver
- Linear Fresnel reflector
- Parabolic Trough
- Parabolic Dish



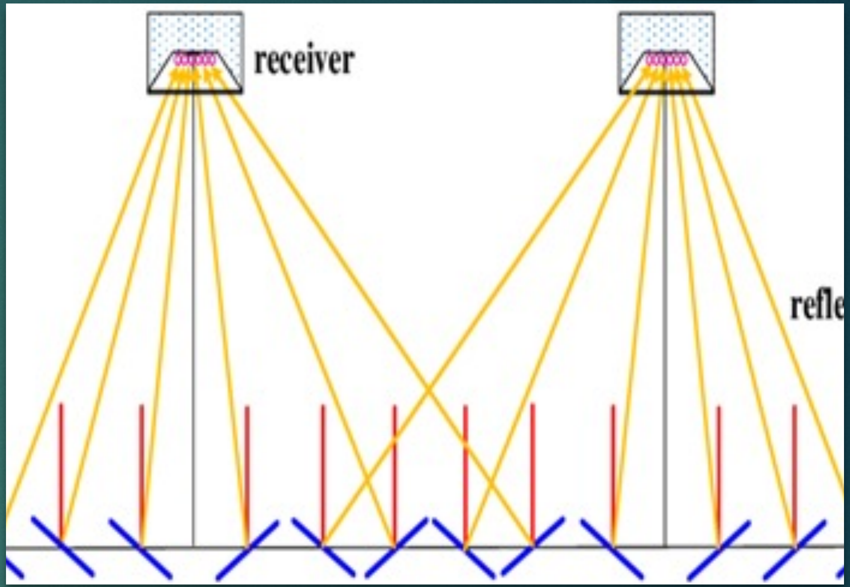
Central Receiver System

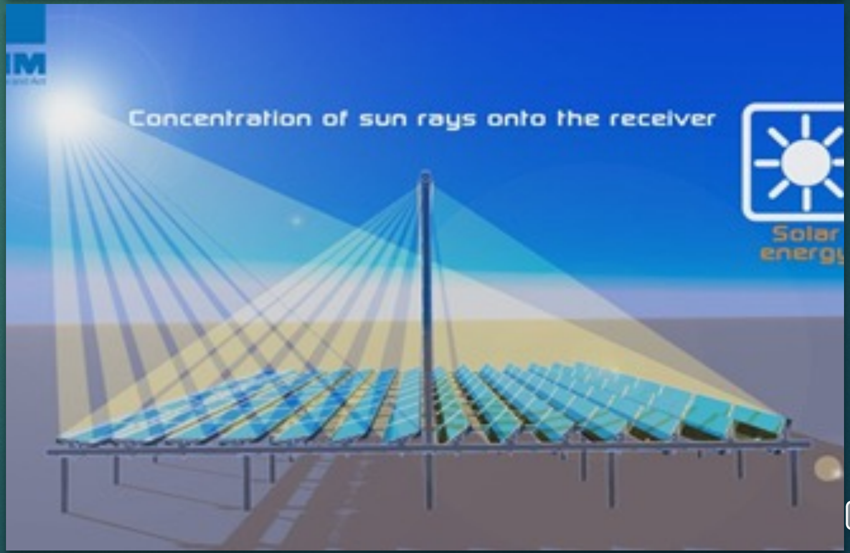
- Central Receiver System is a receiver located on top of a tower to receive energy from the flat distributed mirrors



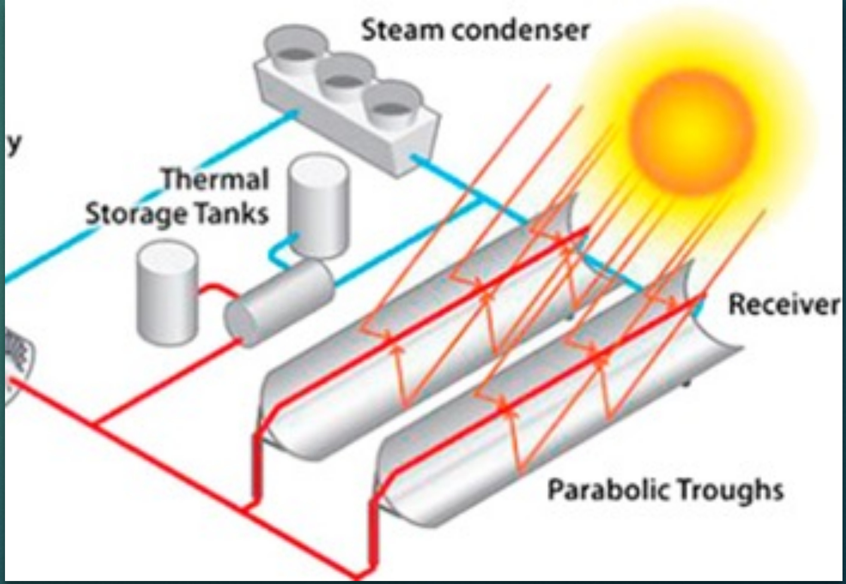
Linear Fresnel Reflector

- Linear Fresnel reflector or IFR is a reflector that concentrate sunlight and send it to the receiver that is located above the mirror





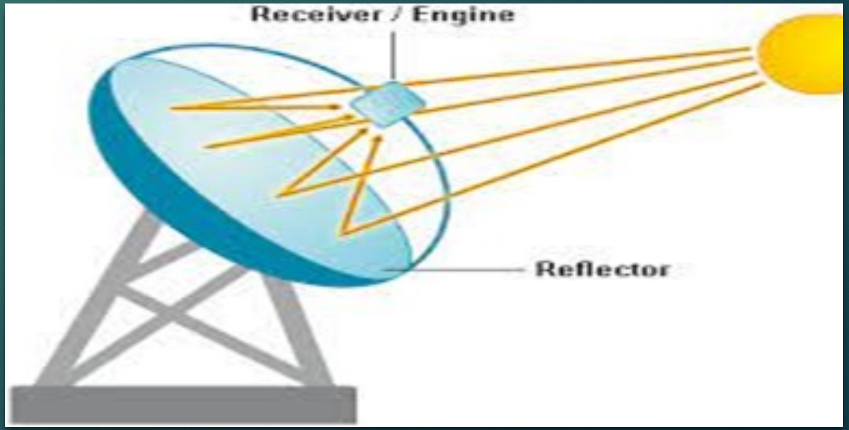
Parabolic Trough Reflector

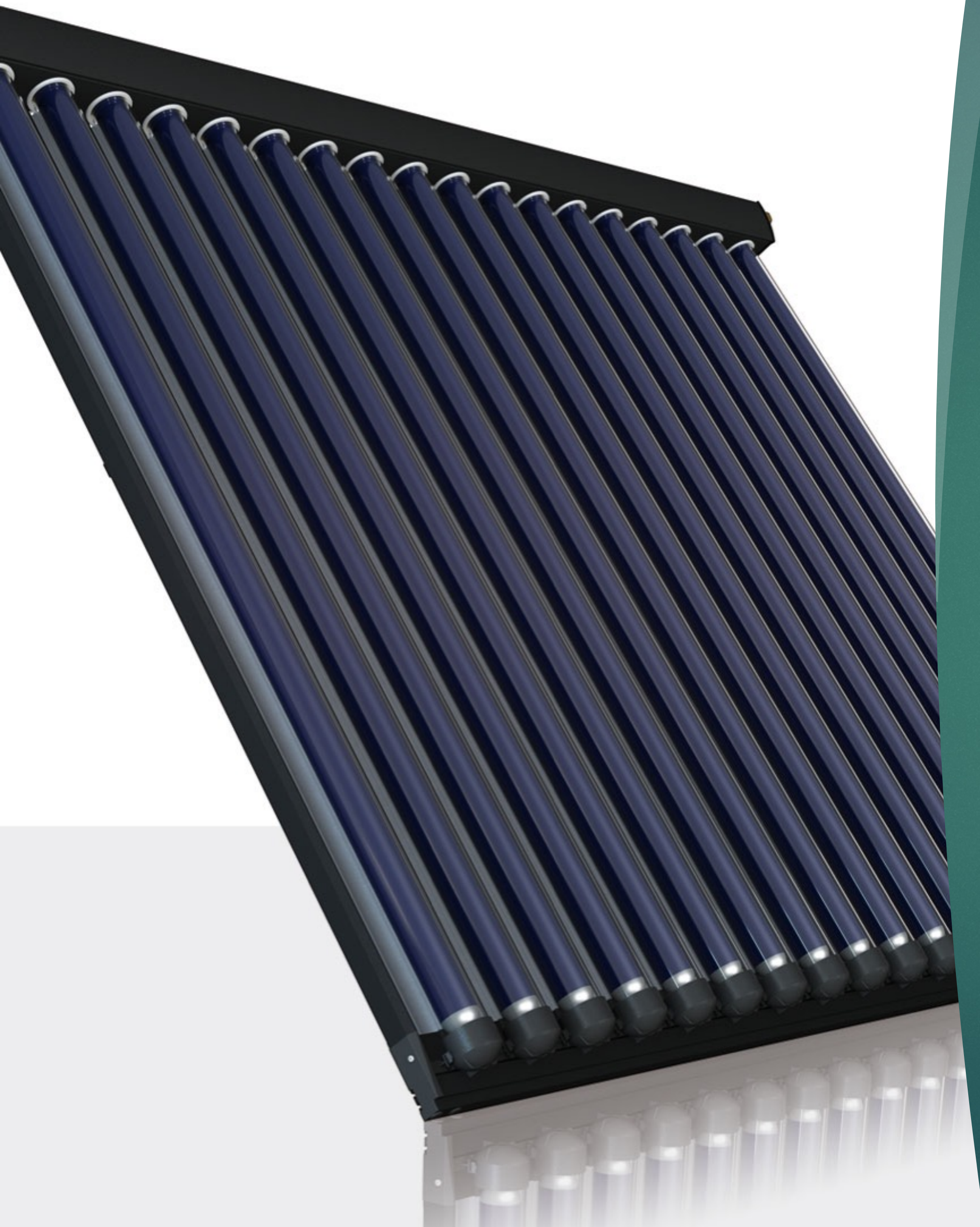


- **PTR**, are made by bending a sheet of polished aluminum that is reflective and it is called a parabola shape

Parabolic Dish

- Solar dish system uses a mirrored dish which is similar to satellite dish or even larger. It is used to reduce costs the mirrored dish is made of small little flat mirrors.



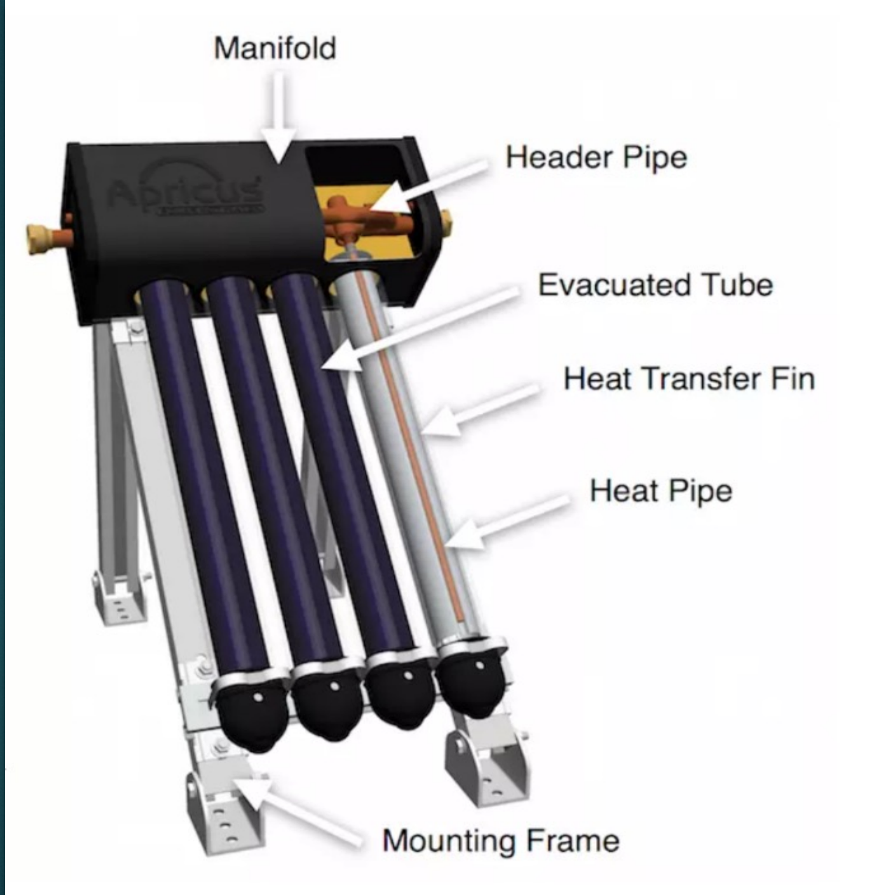


Team 2

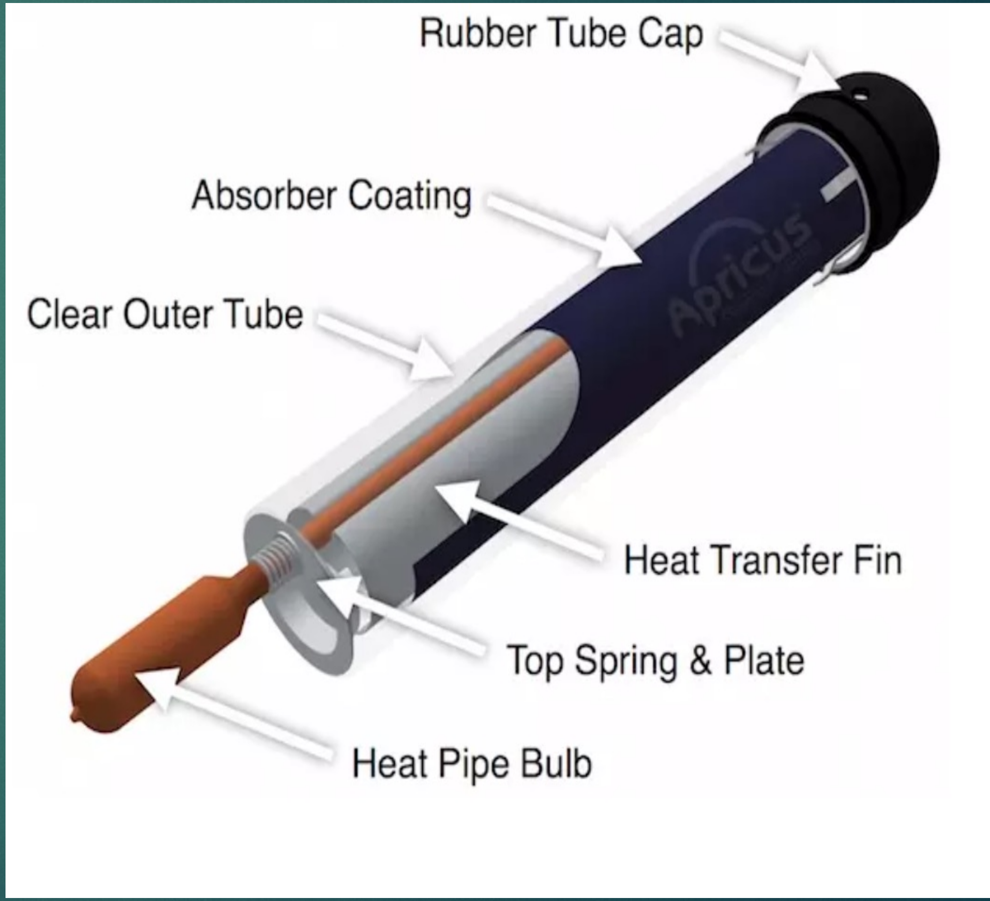
Solar Hot Water System

Faisal, Ulises, Ashley

Background



Apricus ETC-solar collectors

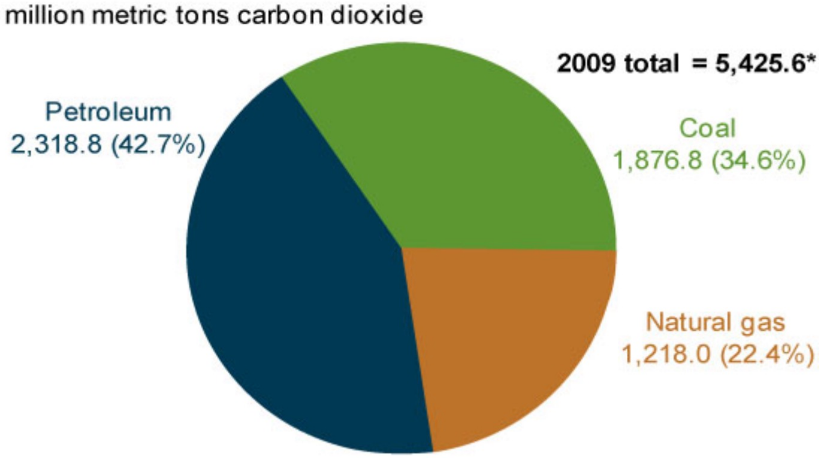


Apricus ETC-solar collectors

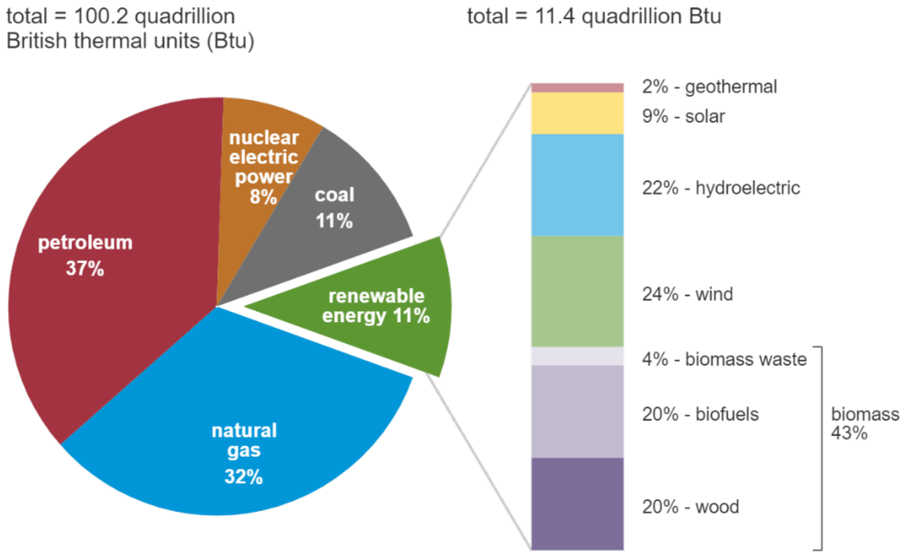
Benefits & Mission Statement

- A stable energy supply
- Free energy source
- Reduced carbon footprint
- Efficiency: Around 80% of radiation turn into heat
- Low maintenance: very low maintenance that lasts for 20 years

Figure 2. U.S. energy-related carbon dioxide emissions by major fuel, 2009



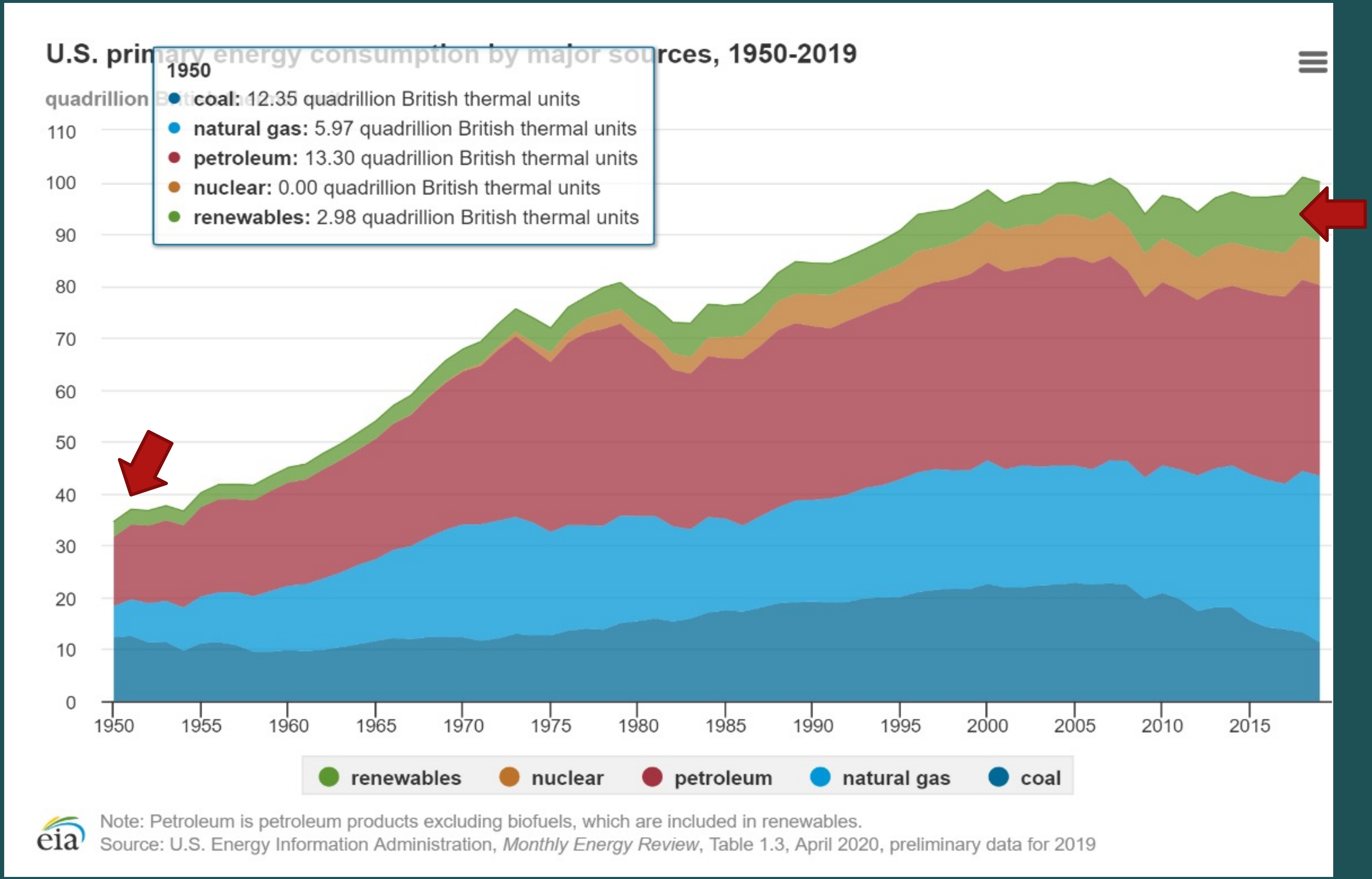
U.S. primary energy consumption by energy source, 2019



Note: Sum of components may not equal 100% because of independent rounding.
Source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 1.3 and 10.1, April 2020, preliminary data

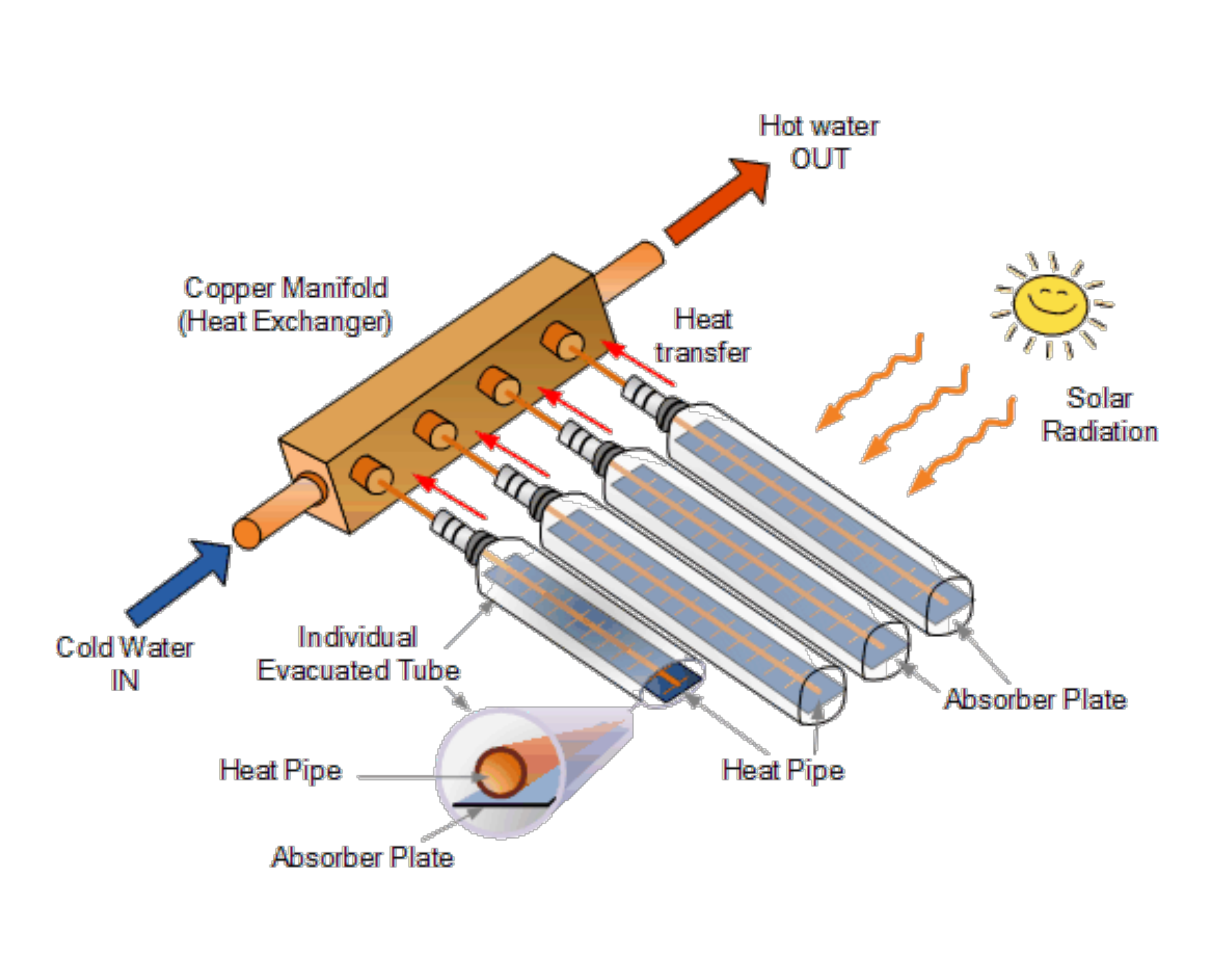
Apricus ETC-solar collectors

United States Energy Consumption



Apricus ETC-solar collectors

Concept & Design



Alternative-energy-tutorial

Efficiency Analysis

$$\eta = \frac{Q_{out}}{Q_{in}}$$
$$P_{in,eff} = \eta_{sun} P_{in}$$
$$Q_{in} = P_{in,eff} \Delta \mathrm{T}$$
$$Q_{out} = mC_p \Delta \mathrm{T}$$
$$\Delta \mathrm{T} = \mathrm{T_f} - \mathrm{T_i}$$
$$1Wh = 3.41Btu$$
$$1gal = 0.1336ft^3$$
$$\rho_{water} = 62.43 \frac{lbs}{ft^3}$$
$$C_{p,water} = 1 \frac{Btu}{lb\ °F}$$

- Q_{out} = Heat energy out
- $Q_{in} = Heat\ energy\ in$
- η_{sun} = Sunlight heat efficiency
- $P_{in} = Power\ of\ the\ Source\ (sun)$
- $\eta = Efficiency$

Efficiency Analysis (Flat Plate)

$$Q'' = F[G\tau\alpha - U(T_c - T_a)]$$

Energy in – Energy out

$$\eta_c = \frac{Q''}{G} = \frac{Actual\ energy\ into\ working\ fluid}{Maximum\ radiation\ energy\ available}$$

$$Q'' = Heat\ flux\ absorbed\ by\ collector\ \left(\frac{heat\ transfer}{unit\ area}\right)$$

$$F = Design\ factor\ of\ collector\ (efficiency\ factor)$$

$$G = Total\ normal\ incident\ radiation\ \left(\frac{W}{m^2}\right)$$

$$T_a = ambiend\ temperature$$

$$T_c = collector\ fluid\ temperature$$

$$U = heat\ loss\ coefficient$$

$$\alpha = absorbance\ collector\ (material\ property)$$

$$\tau = transmittance\ of\ enclosure\ cover$$

$$\eta_c = efficiency\ of\ collector$$

Energy studies 2nd edition by William Shepherd, David W. Shepherd

Assembly

Mini Solar Model

Water pump inside insulated cooler (1 gallon Water)

Evacuated tube Solar Hot water system

Test Run #1

Parameter	Symbol	Value	Units
Total Volume of water:	V	1	Gallons
Initial Temperature of Water:	T_i	25.9°	°C
Time Passed:	Δt	1	Hour(s)
Final Temperature of Water:	T_f	32.8°	°C

Initial Temperature (T_i)

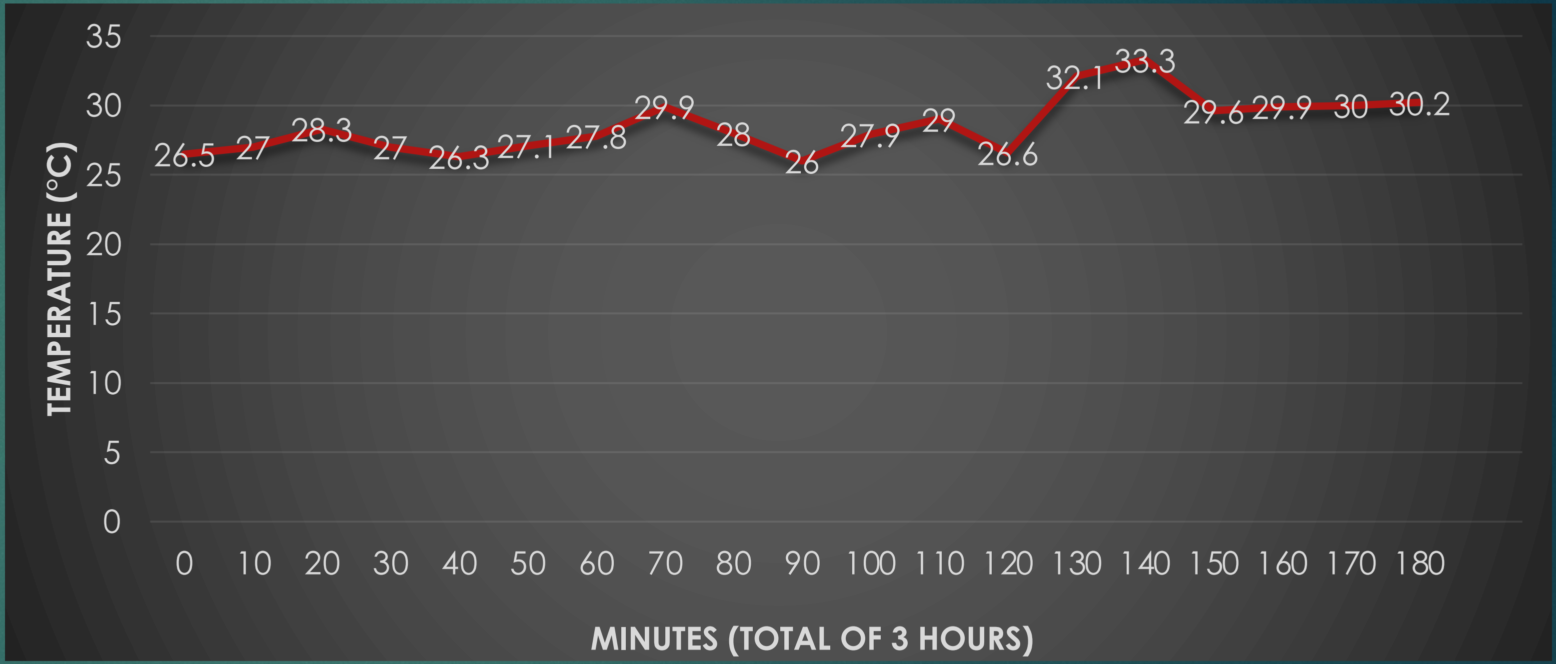
Final Temperature (T_f)

Test Run #2

Parameter	Symbol	Value	Units
Total Volume of water:	V	1	Gallons
Initial Temperature of Water:	T_i	26.5	°C
Time Passed:	Δt	3	Hour(s)
Final Temperature of Water:	T_f	30.2	°C

Initial Temperature (T_i)

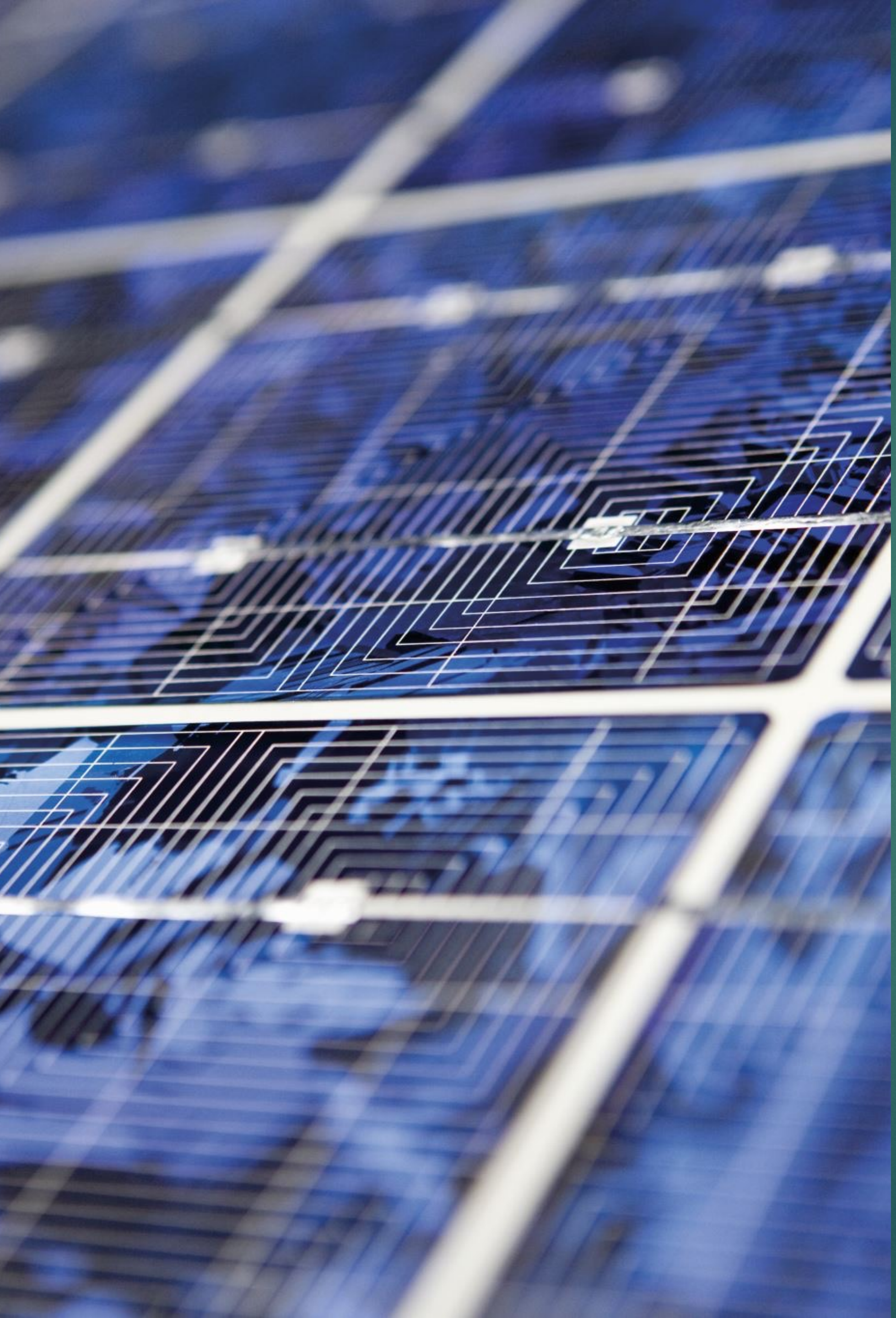
Final Temperature (Tf)



Difference in Temperature per 10 min

Trials & Error

- Cooler not fully insulated
- Cloudy weather
- Loss of water (tubing)



Team 3

Charging System + Energy Analysis (Generation, Consumption)

Napat, Kailen, Alex

Project Background

- history of solar...
- solar goals of California...
- current operation/issues with solar integration in power grid…
- solar panel…
- battery storage…
- solutions…

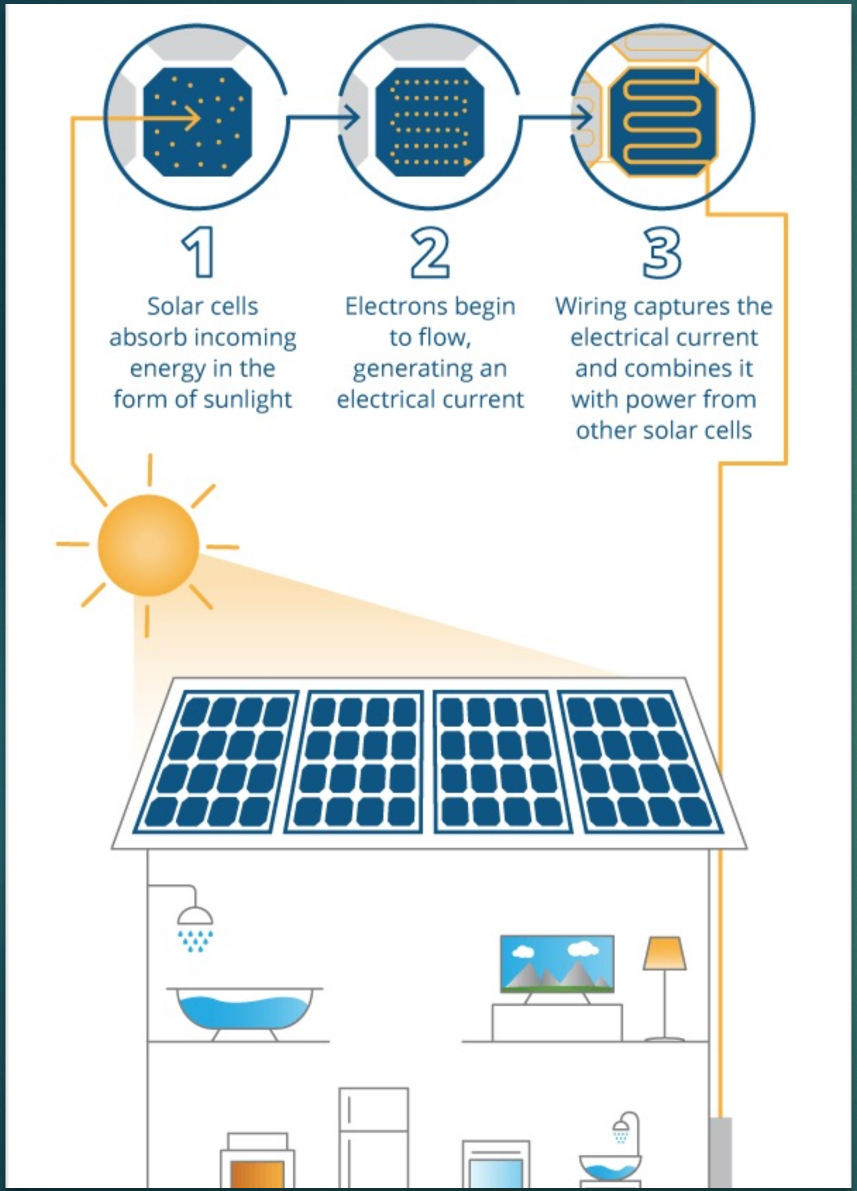
Project Importance

- Within the solar trailer, we need to be mindful of how much power is being generated, stored, and used by appliances.
  - Estimate power generated
  - Acknowledge the minimum voltage level for batteries to maintain health
  - Research, select, and estimate power consumed by desired appliances

What Makes A Solar Power System?

Four main components to a solar power system:

- Solar Panels
- Inverters
- Solar Module Racking (to be discussed more during 3D printing section)
- Solar Batteries



Solar Panels

PHOTOVOLTAIC CELLS ABSORB SUNLIGHT AND CONVERTS THAT ENERGY INTO A DC CURRENT.

Mini Model Components

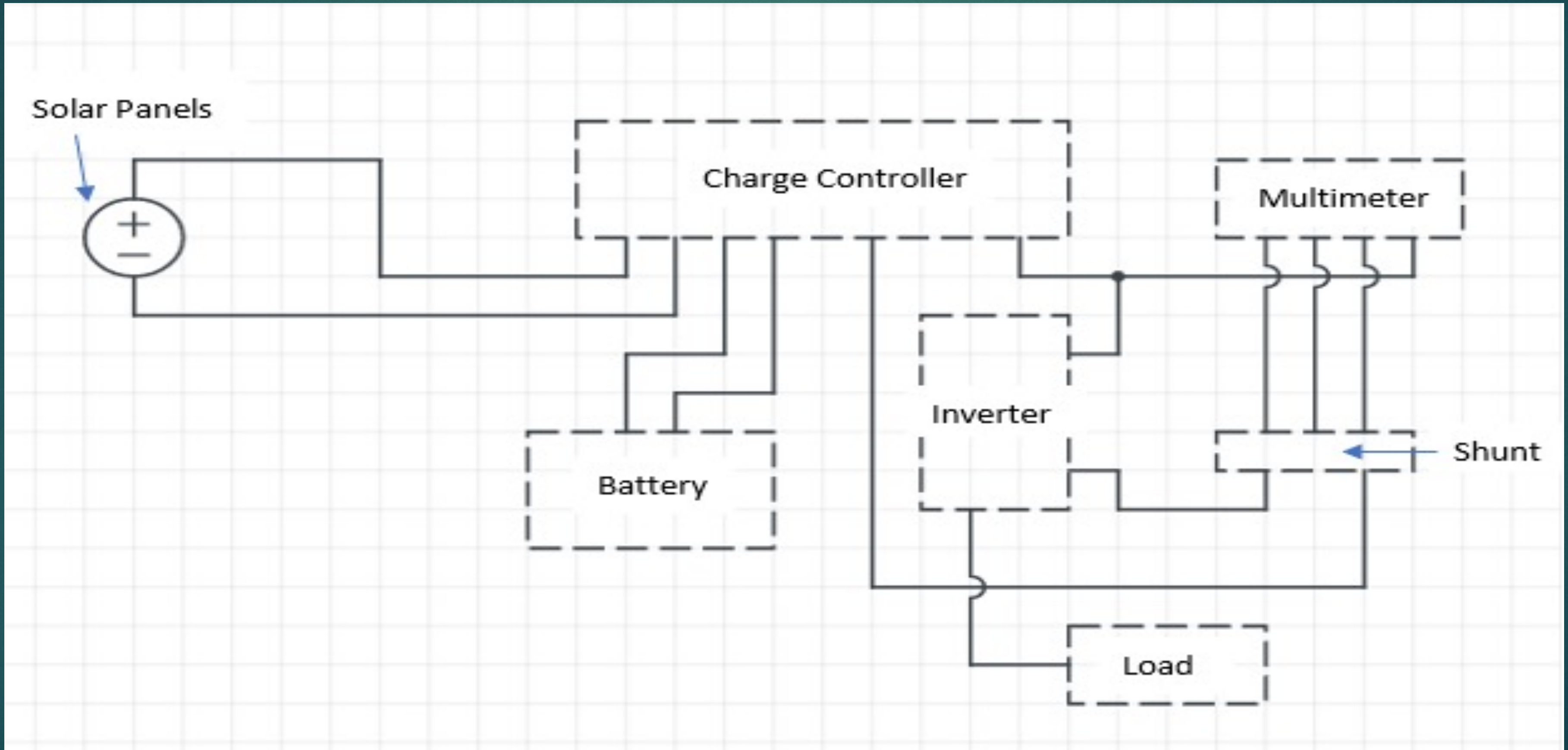
Power Inverter

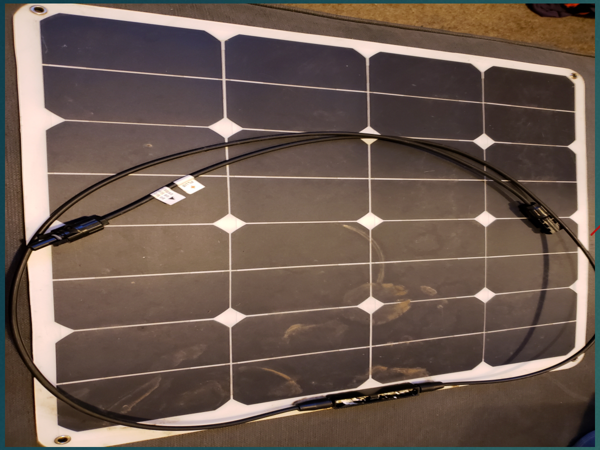
- GELOO 300 W Power Inverter (Input: DC12V & Output:AC 110V±10%)

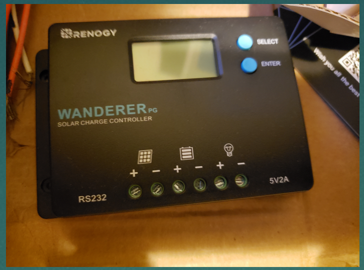
Solar Battery

- MightyMax (12V 18Ah) Lead-Acid Rechargeable Battery

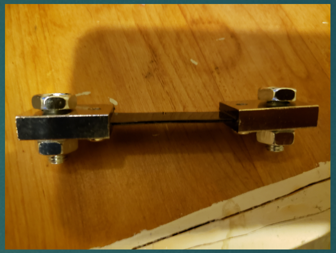
Mini Model Circuit Diagram (First Draft)

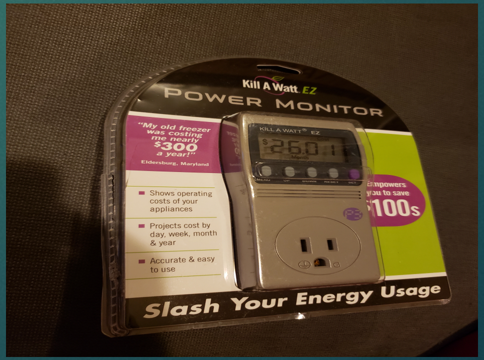






Equipment Used





Energy Analysis

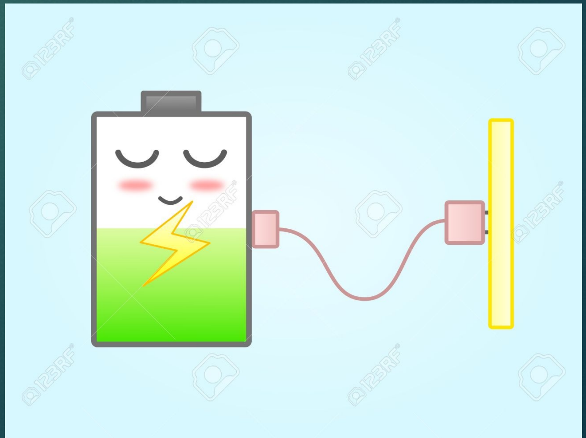
- To estimate the electricity generated in an output of a photovoltaic system:

E (kwh) = Area (m^2)*r (solar panel yield percentage)*H(annual average solar radiation on the tilted panels)*PR (performance ratio)

- Performance ratio will experience losses due to Inverter, AC & DC cables, dirt/particles between the face of the panels, shade and temperature variations (overcast, storm, night, etc.)

Power Consumption

- Formula for Determining Appliance Cost:
- Daily Cost = Wattage (in mW) x Usage per day (in hours) x Energy Cost (cents per kWh)
  - Ex) Appliance operates at 1500W for 3 hours a day. Your utility company charges 0.10c per kWh.
    - (1500W/1000) * 3 hours * 0.10c = $0.45 per daily operation
- Wattage can be found in product description
- Usage per day can just be estimated, or observed by power meter
- Energy cost varies by region, time used, and provider
  - US average is approximately $0.12/kWh



Appliance Characteristic Chart

Appliance Characteristic Chart										
Appliance		Dimensions (WxDxH, In)	Weight (lbs)	Price ($)	Wattage (W)	Estimated Daily Usage (in hours)	Estimated Monthly Usage (in hours)	Estimated Daily Cost (@ $0.12/kWh)	Estimated Monthly Cost (@ $0.12/kWh)
Stove		-	-	-	-		-	-	-
Brand:	Techwood	22.5x9.9x4.3	8.83	$72.98	1800	5	150	$ 1.08	$ 32.40
Brand:	CUSIMAX, electric	21.5x15x4.7	8	$93.99	1250	5	150	$ 0.75	$ 22.50
Toaster		-	-	-	-	-	-	-	-
Brand:	Whall	13.19x9.13x7.52	3.65	$39.99	1200	0.2	6	$ 0.03	$ 0.86
Mini Fridge		-	-	-	-	-	-	-	-
Brand:	Euhomy	19.4x19.9x33.5	53.1	$199.99	286	24	720	$ 0.82	$ 24.71
Brand:	Bossin	20.1x19x33.5	44.1	$209.99	253	24	720	$ 0.73	$ 21.86
Coffee Maker		-	-	-	-	-	-	-	-
Brand:	Farberware	9.2x8.7x7	2.25	$29.99	900	0.5	15	$ 0.05	$ 1.62
Brand:	Black&Decker	8.25x12.25x11	4.5	$22.49	950	0.5	15	$ 0.06	$ 1.71
Television		-	-	-	-	-	-	-	-
Brand:	TCL	38.2x22.3x3.3	15.4	$228.00	63	4	120	$ 0.03	$ 0.91
Brand:	Vizio	22.1x13.3x2.9	8.73	$149.88	58	4	120	$ 0.03	$ 0.84
Microwave		-	-	-	-	-	-	-	-
Brand:	Amazon Basics	17.3x10.1x14.1	21.9	$74.99	700	1	30	$ 0.08	$ 2.52
Heat Pump		-	-	-	-	-	-	-	-
Brand:	Senville	30.31x11.81x21.85	65	$799.99	1200	8	240	$ 1.15	$ 34.56

Design Decision Matrix

Appliance Design Decision Matrix								
Appliance (1 = low, 5 = high)		Size	Weight	Cost	Availability	Reviews	Energy Consumption	Overall Score
Stove		-	-	-	-	-	-	-
Brand:	Techwood	3	4	4	5	4	4	24
Brand:	CUSIMAX, electric	3	4	3	5	3	3	21
Toaster		-	-	-	-	-	-	-
Brand:	Whall	3	4	3	4	4	4	22
Mini Fridge		-	-	-	-	-	-	-
Brand:	Euhomy	3	3	3	3	4	4	20
Brand:	Bossin	3	4	3	3	2	4	19
Coffee Maker			-	-	-	-	-	-
Brand:	Farberware	3	4	4	4	3	4	22
Brand:	Black&Decker	2	2	3	5	3	4	19
Television		-	-	-	-	-	-	-
Brand:	TCL	4	2	2	4	5	3	20
Brand:	Vizio	2	3	3	4	4	3	19
Microwave		-	-	-	-	-	-	-
Brand:	Amazon Basics	3	3	2	5	4	3	20
Heat Pump		-	-	-	-	-	-	-
Brand:	Senville	1	2	2	3	3	4	15

Total Monthly Energy Cost
$97.58
Total Appliance Cost
$1,576.00

By estimation, the solar trailer would pay off the appliances after 16 months.

K-12 Engagement/Interaction

Objective

- Demonstrate how easy using solar power can be
- Demonstrate the number of appliances powered
- Make the case that solar power is a viable and needed option
- Make the learning experience engaging and fun

Overview

- 3 Levels of project breakdown:
  - Grades K-6
    - Generating power using a hand crank
  - Grades 7-8
    - Given a sized solar system and a chart of appliances, which appliances would you like in your home?
  - Grades 9-12
    - Powering their phone by constructing a small scale solar powered circuit

Project Visions

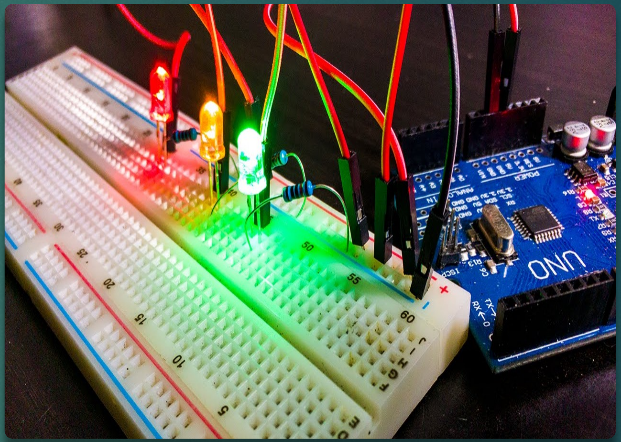
Grades K-6

- Hand crank to generate electric charge to power a small device.
- Distinguish between passive and active generation of power

Grades 7-8

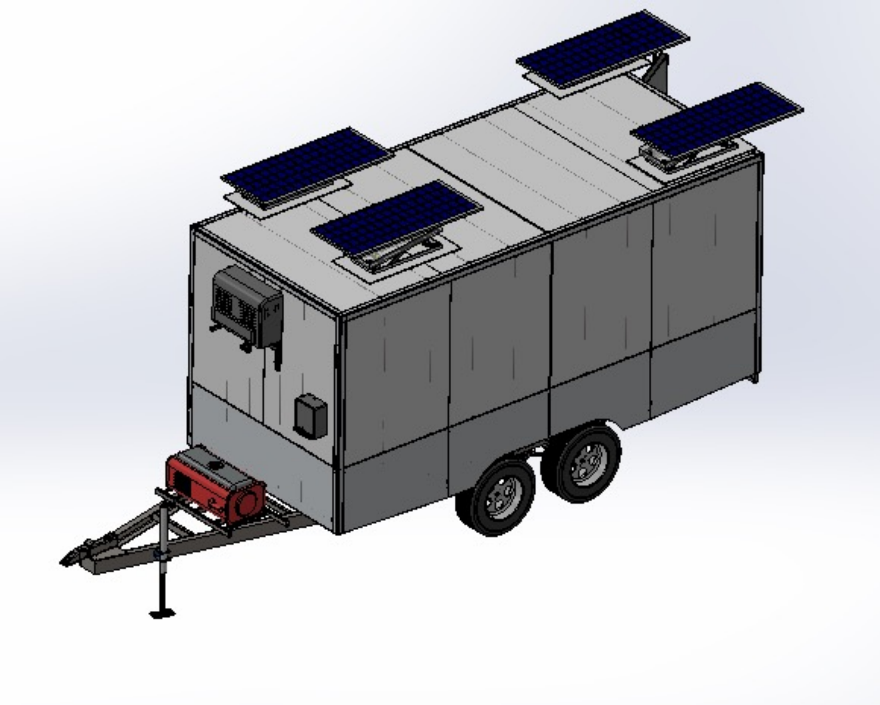
- Students would think about appliances they use most while keeping their consumption in mind
- Could also help students conserve energy at home by eliminating phantom energy

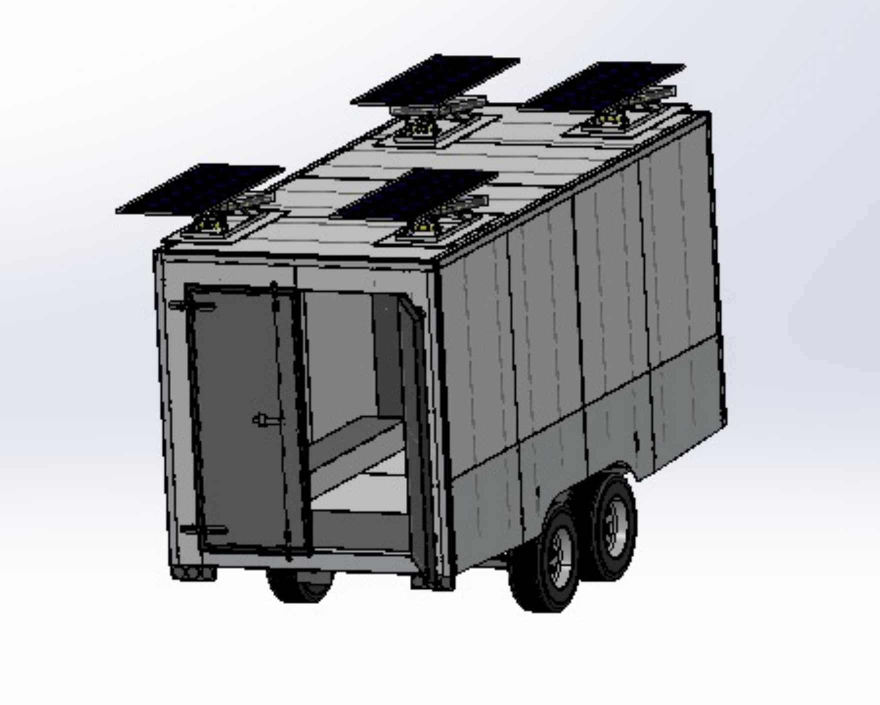
Grades 9-12



- Expose students to small circuitry
- Interactive and hands on learning
- Troubleshooting experience

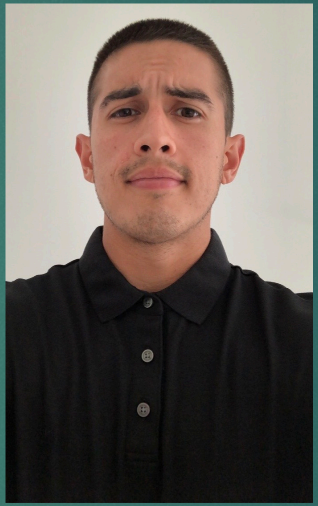
Solar Power Trailer SolidWorks Prototype





Team 4:

3D Printing & Applications

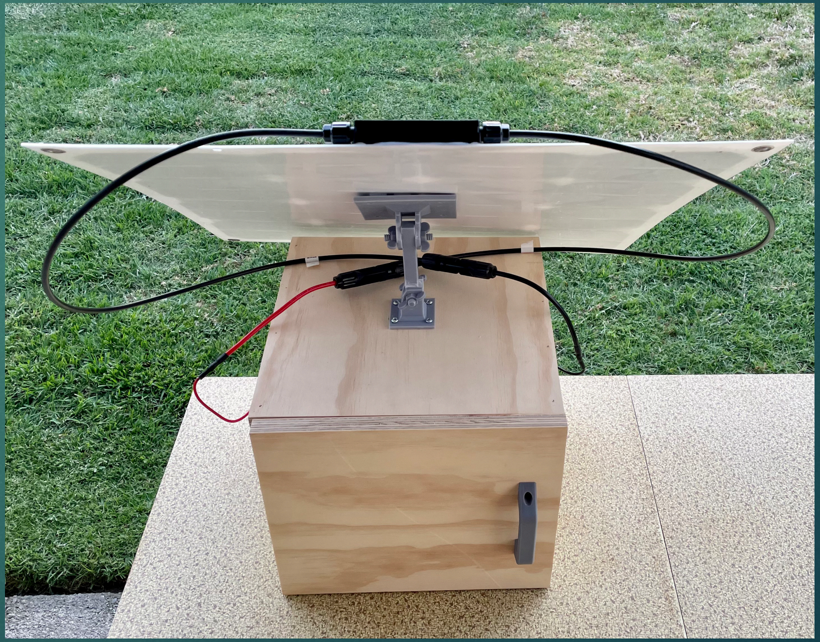


Steven Garcia

Sergio Miranda

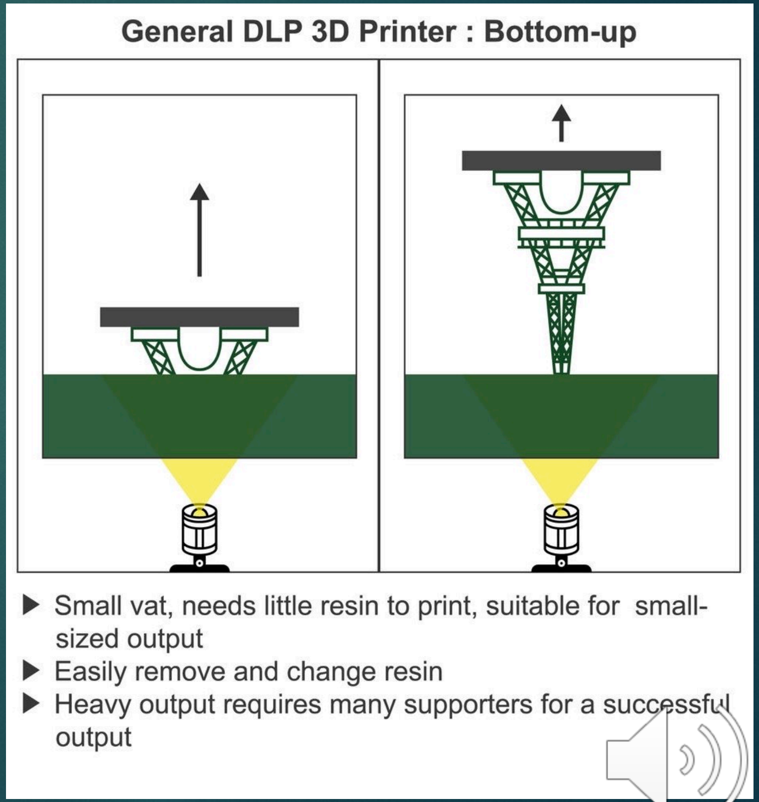
Background

- Our team was focused on 3D printing a mounting system and other various parts as well as building a prototype solar photovoltaic system.

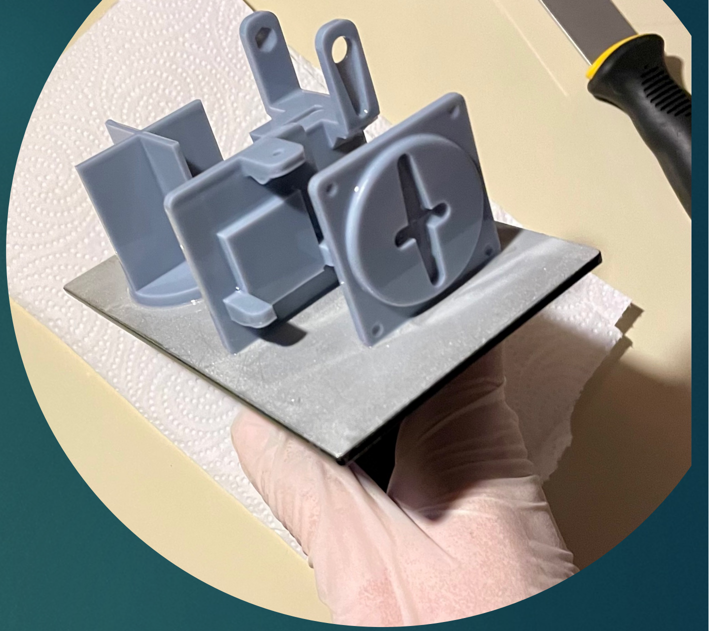


Resin 3D Printing

- 3D Printer - Elegoo Mars Pro 2
- Uses – Build & Design
- Advantages - Fast Prototyping
- 3D Printing Process
- Curing

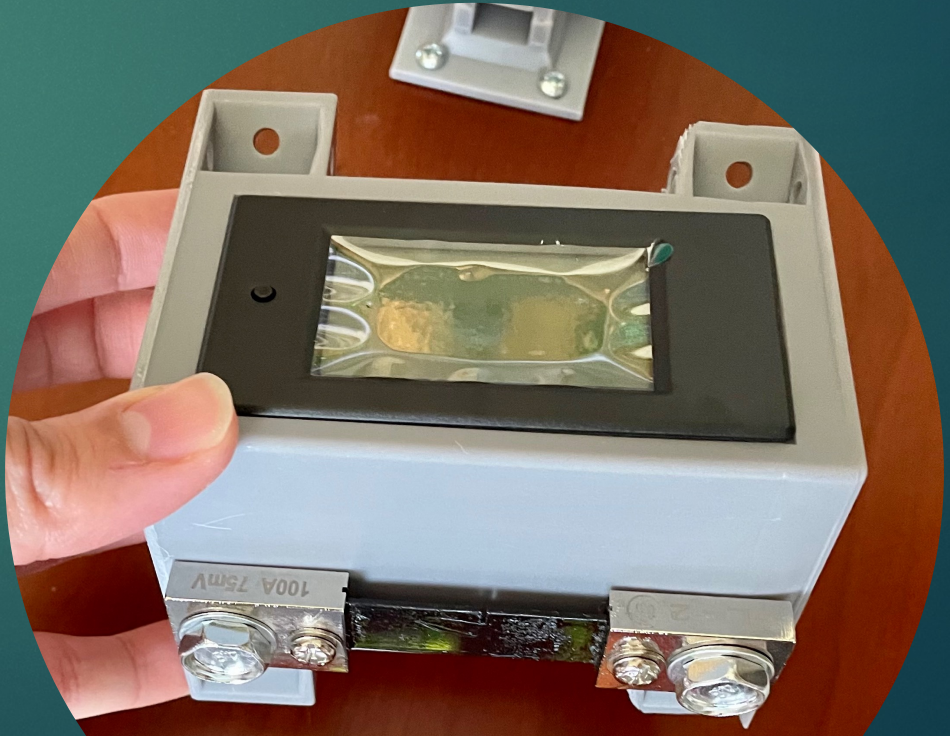


3D Print Manufacturing



3D Printed Parts

Total Hours 3D Printing: 50+ Hrs



Solar Box

- Box Build Size: H10in x W12in x L12in
- Total Weight: 26.2 lbs.
- 3D Printed Parts: 2 Axis Solar Panel Bracket, Screws, Wing Nuts, Shunt Mount & Door Handle
- Real World Energy Use: 163 Wh

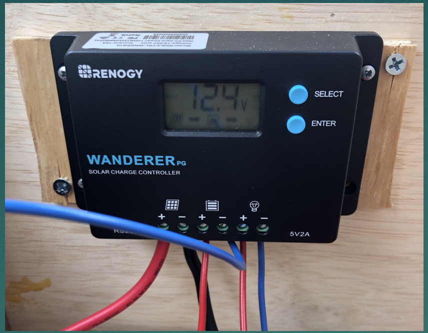
Charging Rate		
Cloudy Day	Sunny Day	Result
~0.0025 volts/min	~0.0172 volts/min	7x more power on a sunny day than on a cloudy day

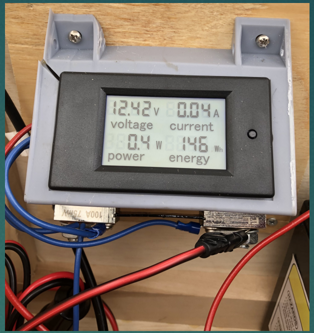
Solar Cart

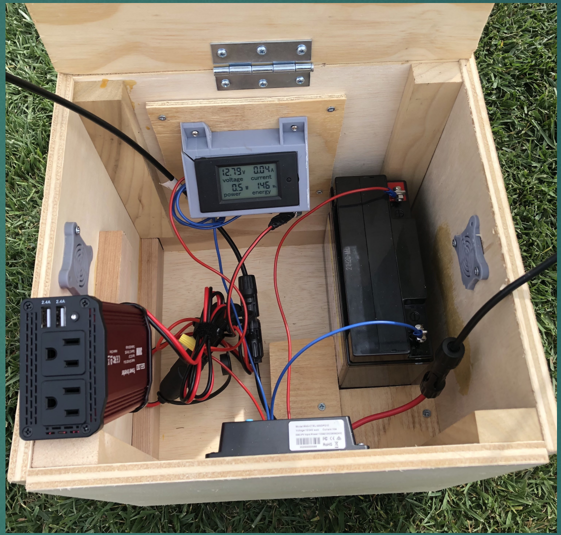
- Box Size: H12in x W13in x L12.5in
- Total Weight = 27.8 lb.
- 3D Printed Adjustable Solar Panel Mount
- Solar Panel attached with Velcro
- 3D Printed Screws and Wing Nuts
- 3D Printed Vents
- 3D Printed Multimeter and Shunt Case

Solar Panel Specification	
Size	22.0 x 21.3 x 0.118 in
Weight	2.4 lb
Optimal Power (Pmax)	50W +/- 0.25W
Working Voltage	18V +/- 0.3V
Working Current	2.7A +/- 0.15 A
Short circuit Current	2.9A +/- 0.15A
Open Circuit Current	20V +/- 0.8V

Solar Cart



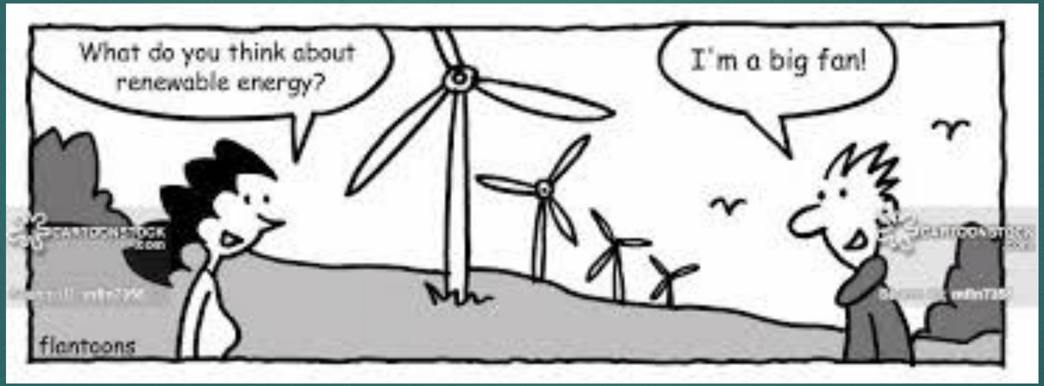




Charging Rate		
Cloudy Day	Sunny Day	Result
~0.0076 volts/min	~0.079 volts/min	Charge rate10x faster on a Sunny Day

Community Demonstration

- Demonstrate by showing the Solar Box/Cart to schools and the neighborhood.
- Educate about Solar and Sustainability
- Portable charging station



Questions?