% NOTE: Copy and paste your section of this ‘Start Here’ document into MatLab % to get started.

%

% In this document Green is for constants you enter, Lime is for

% calculations or operations you need to perform, and Blue is for code that

% should be left unchanged.

%

% Title: Water Pump Energy Systems

%

% Description:

%

% Author:

%

% Date of last revision:

%

% Clear variables and close open figures

%

% ================ Section 1 - Establish Site Parameters ==================

%

% Create Constants for the Latitude and Longitude in degrees

% Round the values for Latitude and Longitude

% Use xlsread to read Earth Skin Temp data and store it in a matrix called Tamb

% Use indexing to reduce Tamb to a 1 x 12 vector of temperatures for the site latitude and longitude

% Create a constant for the population

% Create a constant for the daily water consumption per person in Liters

% Calculate the total daily volume of water consumed in Liters

% Convert the daily volume of water consumed to m^3

% Calculate the flow rate in m^3/s

% Create a constant for the water table depth in feet

% Convert the water table depth to meters

% Add 5 m to the water table depth to calculate the pump depth

%

% ==================== Section 2 - Determine Daily Load ===================

%

% Pipe parameters (NOTE: You are advised to leave these values unchanged)

D\_pipe=4.026; % Diameter (in inches) of nominal 4 inch PVC pipe

D\_pipe=D\_pipe\*0.0254; % Diameter in meters

epsilon=0.0000015;% Absolute roughness of PVC pipe in meters

h\_tank=5; % Height of discharge tank in meters.

k\_entrance=0.5; % Loss coefficient at the entrance of the PVC pipe

k\_elbow=1.1; % Loss coefficient at a sharp 90 degree elbow

n\_elbow=4; % Number of elbows

k\_exit=1; % Loss coefficient at the exit from the PVC pipe to the storage tank

%

% Calculate cross-sectional area of PVC pipe in square meters

%

nu=0.000001004; % Kinematic viscosity (in m^2/s) of water at 20 C (NOTE: Leave

% Unchanged)

%

% Calculate the velocity of water (m/s) through the pipe

% Calculate the Reynold's number

% Use an if/then statement to set f = 0 if flow is zero

% Use indexing or if/then statements to solve for f (for laminar versus

% non=laminar flow)

% Make sure to end conditional statements.

%

g= 9.8; % acceleration of gravity in m/s^2 (DO NOT CHANGE)

%

% Solve for Major and minor head losses

%

rho = 998.2; % Density of water at 20 C in kg/m^3 (DO NOT CHANGE)

efficiency=0.8;% Pump efficiency (NOTE: You are advised to leave these values

% unchanged)

%

% Solve for the daily energy required in MegaJoules

%

% ============== Section 3 - Determine Daily Solar Insolation =============

%

% Create a 1 x 12 vector for the number of each month of the year

%

% NOTE: DO NOT CHANGE MeanDay

MeanDay=[17,47,75,105,135,162,198,228,258,288,318,344]; % Ave day of month (Klein,1977)

%

% Create a constant for the albedo/Ground reflectivity See

% https://www.climatedata.info/forcing/albedo/

% Create a constant for the tilt angle of panels in degrees (Start with Beta

% equal to the absolute value of the Latitude. The test different values)

% Create a matrix for H values read from excel file for Global Horizontal

% Solar kWh/m^2/day

% Use indexing to reduce H to a 1 X 12 vector for the values at the Latitude

% and Longitude

% Convert H from kWh/m^2/day to MJ/m^2/day

% Create a vector called delta for the sun's declination angle in degrees for % each Mean Day

% Convert Latitude, Longitude, Beta, and delta from degrees to radians

%

% Sunset hour angle on a horizontal surface for each Mean Day in radians

wsh=acos(-tan(Latitude)\*tan(delta)); % DO NOT CHANGE

%

% Calculate the Sunset hour angle on tilted panels in radians

%

% Ratio of Beam radiation on a tilted to horizontal surface for each Mean Day

% DO NOT CHANGE

if Latitude>=0 % Ratio for North hemisphere

 Rb=(cos(Latitude-Beta)\*cos(delta).\*sin(ws)+...

 ws\*sin(Latitude-Beta).\*sin(delta))./...

 (cos(Latitude)\*cos(delta).\*sin(ws)+...

 ws\*sin(Latitude).\*sin(delta));

else % Ratio for South hemisphere

 Rb=(cos(Latitude+Beta)\*cos(delta).\*sin(ws)+...

 ws\*sin(Latitude+Beta).\*sin(delta))./...

 (cos(Latitude)\*cos(delta).\*sin(ws)+...

 ws\*sin(Latitude).\*sin(delta));

end

%

% Clearness Index (DO NOT CHANGE)

Gsc=1.367; % Solar constant in kW/m^2

Gon=Gsc\*(1+0.033\*cos(MeanDay\*2\*pi/365)); % Extra-terrestial insolation on a

% normal surface

Ho=24\*Gon/pi.\*(cos(Latitude)\*cos(delta).\*sin(wsh)+...

wsh\*sin(Latitude).\*sin(delta)); % Daily Extra-terrestial solar energy

%(kWh/m^2/day) on a horizontal

% surface

KT=H./(Ho\*3.6); % Clearness Index

%

% Hd (Diffuse Radiation) --> Collares, Pereira, Rhal relation (DO NOT CHANGE)

Hd(KT<=0.17)=0.99\*H(KT<=0.17);

Hd(KT>0.17 & KT < 0.75)=(1.188-2.272\*KT(KT>0.17 & KT<0.75)+...

 9.473\*(KT(KT>0.17 & KT<0.75)).^2-21.865\*(KT(KT>0.17 & KT<0.75)).^3+...

 14.648\*(KT(KT>0.17 & KT<0.75).^4)).\*H(KT>0.17 & KT<0.75);

Hd(KT>0.75 & KT < 0.8)=(0.632-0.54\*KT(KT>0.75 & KT<0.8)).\*H(KT>0.75 & KT<0.8);

Hd(KT>=0.8)=0.2\*H(KT>=0.8);

%

% Calculate the average radiation incident on tilted solar panels in MJ

%

% ============== Section 3 - Determine Daily Solar Insolation =============

%

% Month vectors

MonthNumber=linspace(1,12,12); % Months of year

MeanDay=[17,47,75,105,135,162,198,228,258,288,318,344]; % Ave day of month %(Klein,1977)

%

% Ground reflectivity

albedo=0.2; % albedo at site See https://www.climatedata.info/forcing/albedo/

%

% Tilt angle of panels

Beta = abs(Latitude); % example) tilt angle = absolute value of Latitude

%

% Vector of values for H MJ/day

H=xlsread('GlobalHorizontalSolar.xlsx'); % H values worldwide in kW/m^2/day

H=H((H(:,1)==Latitude)& (H(:,2)==Longitude),3:end-1); % H values at site

H=H\*3.6; % H values in MJ/m^2/day

%

% Create a vector for the sun's declination angle for each Mean Day

delta=23.45\*sin(2\*pi\*(284+MeanDay)/365); % Declination angle in degrees

%

% Convert angles to radians

delta=delta\*pi/180;

Latitude = Latitude\*pi/180;

Longitude = Longitude\*pi/180;

Beta=Beta\*pi/180;

%

% Sunset hour angle on a horizontal surface for each Mean Day

 wsh=acos(-tan(Latitude)\*tan(delta)); % Sunset angle on horizontal in radians

 %

 % Sunset hour angle on tilted panels

if Latitude>=0

 ws=min(acos(-tan(Latitude)\*tan(delta)),...

 acos(-tan((Latitude-Beta))\*tan(delta))); % Sunset angle on panels in North

% hemisphere

else

 ws=min(acos(-tan(Latitude)\*tan(delta)),...

 acos(-tan(Latitude+Beta)\*tan(delta))); % Sunset angle on panels in South

% hemisphere

end

%

% Ratio of Beam radiation on a tilted to horizontal surface for each Mean Day

if Latitude>=0 % Ratio for North hemisphere

 Rb=(cos(Latitude-Beta)\*cos(delta).\*sin(ws)+...

 ws\*sin(Latitude-Beta).\*sin(delta))./...

 (cos(Latitude)\*cos(delta).\*sin(ws)+...

 ws\*sin(Latitude).\*sin(delta));

else % Ratio for South hemisphere

 Rb=(cos(Latitude+Beta)\*cos(delta).\*sin(ws)+...

 ws\*sin(Latitude+Beta).\*sin(delta))./...

 (cos(Latitude)\*cos(delta).\*sin(ws)+...

 ws\*sin(Latitude).\*sin(delta));

end

%

% Clearness Index

Gsc=1.367; % Solar constant in kW/m^2

Gon=Gsc\*(1+0.033\*cos(MeanDay\*2\*pi/365)); % Extra-terrestial insolation on a

% normal surface

Ho=24\*Gon/pi.\*(cos(Latitude)\*cos(delta).\*sin(wsh)+wsh\*sin(Latitude).\*sin(delta)); % Daily Extra-terrestial solar energy (kWh/m^2/day) on a horizontal surface

KT=H./(Ho\*3.6); % Clearness Index

%

% Hd (Diffuse Radiation) --> Collares, Pereira, Rhal relation

Hd(KT<=0.17)=0.99\*H(KT<=0.17);

Hd(KT>0.17 & KT < 0.75)=(1.188-2.272\*KT(KT>0.17 & KT<0.75)+...

 9.473\*(KT(KT>0.17 & KT<0.75)).^2-21.865\*(KT(KT>0.17 & KT<0.75)).^3+...

 14.648\*(KT(KT>0.17 & KT<0.75).^4)).\*H(KT>0.17 & KT<0.75);

Hd(KT>0.75 & KT < 0.8)=(0.632-0.54\*KT(KT>0.75 & KT<0.8)).\*H(KT>0.75 & KT<0.8);

Hd(KT>=0.8)=0.2\*H(KT>=0.8);

%

% Average radiation incident on tilted solar panels

Ht=H.\*(1-Hd./H).\*Rb+Hd\*(1+cos(Beta))/2+H\*albedo\*(1-cos(Beta))/2;

%

% ================= Section 4 - Size Solar Solar Array ====================

%

% PV panel parameters: (Jinko Solar JKM260PP-60 used here)

Pmax=260; % maximum power (STC) in Watts

alpha=-0.004; % Temperature coefficient (Change in power per cell temp. above

% 25 C)

Eta=0.1588; % Panel Efficiency

Apanel=1.650\*0.992; % Panel area in meters squared

UnitCost\_Panel=295; % Dollars per solar panel

%

% Number of Solar Panels needed

N\_Panels=max(ceil(Load./(Ht.\*(1+alpha\*(Tamb-25))\*Eta\*Apanel)));

%

%

% ================== Section 5 - Size Battery Storage =====================

%

% NOTE: You are advised to leave these values unchanged)

DOD = 0.5; % Depth of Discharge (Use 50% for longer life)

RTE= 0.80; % Round trip efficiency - Assume ~80%

%

% Select a battery and record its nominal voltage, its capacity, and cost

% Select a number of storage days (how long the system will last w/o sun)

% Calculate the available energy per battery and the required number of

% batteries (Round up to a whole number)

%

% ============== Section 6 - Calculate Electric Generator Size ============

%

%

RunTime\_Estimated= 10; %Estimated Run Time in hours (DO NOT CHANGE)

% Estimated the Required power in Watts assuming a run time of 10 hours

%

% Select a generator and set constants for the actual power, actual

% runtime, fuel tank capacity, and cost

% Calculate the fuel used daily

% ================= Section 7 - Calculate System Costs ====================

%

% Photovoltaic System:

InitialCost\_Solar=N\_Panels\*UnitCost\_Panel+N\_Batteries\*UnitCost\_Battery;

%

% Electric Generator:

UnitCost\_Fuel=3.56;% average cost per gallon in US %EXAMPLE

DailyCost\_Fuel=UnitCost\_Fuel\*Fuel\_Daily;

YearlyCost\_Fuel=DailyCost\_Fuel\*365;

%

d=0.02; % discount rate of money

%

% Calculate the Number of years for generator NPV to equal solar system NPV

%

syms n % Identify variable for Matlab summation

%

% Initialize Variables for Year and Costs

AccumulatedCost\_Generator=InitialCost\_Generator;

N=0;

Year(1)=0;

YearlyCost\_Solar(1)=InitialCost\_Solar;

AccumulatedCost\_Solar(1)=InitialCost\_Solar;

YearlyCost\_Generator(1)=InitialCost\_Generator;

AccumulatedCost\_Generator(1)=YearlyCost\_Generator(1);

% Sum the costs until the initial PV system cost equals the generated

% accumulated cost

while AccumulatedCost\_Generator(end)<InitialCost\_Solar(end)

 N=N+1; % When the loop end the value of N is the years until the generator

% NPV is equal or greater than the solar system NPV

 Year(N+1)=N; % Increment year by 1

 YearlyCost\_Solar(N+1)=0; % Assume no yearly solar costs

 AccumulatedCost\_Solar(N+1)=AccumulatedCost\_Solar(N)+YearlyCost\_Solar(N+1); % Solar

 YearlyCost\_Generator(N+1)=YearlyCost\_Fuel^N; % Yearly

% of fuel with discounted value of money AccumulatedCost\_Generator(N+1)=AccumulatedCost\_Generator(N)+YearlyCost\_Generator(N+1); %accumulated generator cost

end

%

% ================== Section 8 - Display Results ==========================

%

fprintf('\n The Latitude is %d degrees and the Longitude is %d degrees\n',Latitude\*180/pi,Longitude\*180/pi)

fprintf('\n The population is: %d \n',Population)

fprintf('\n The tilt angle of the panels is: %d degrees \n',Beta\*180/pi)

fprintf('\n The required number of solar panels is: %d \n',N\_Panels)

fprintf('\n The power of each solar panel is: %d W \n',Pmax)

fprintf('\n The system is designed for %d Storage Days \n',StorageDays)

fprintf('\n The required number of batteries is: %d \n',N\_Batteries)

fprintf('\n The voltage of each battery is: %d Volts \n',V\_Battery)

fprintf('\n The capacity of each battery is: %d Amp-hour \n',Capacity)

fprintf('\n The total cost of the solar energy system is: $%d \n',InitialCost\_Solar)

fprintf('\n The power of the electric generator is: %.2f kW \n',P\_Gen\_Rated)

fprintf('\n The cost of the electric generator is: $%.2f \n',InitialCost\_Generator)

fprintf('\n The year fuel cost to run the generator is: $%.2f \n',YearlyCost\_Fuel)

fprintf('\n In %.1f years, the accumulated generator system cost will equal the …

 solar energy system costs\n',N)

%

% Display yearly costs of both systems in a table

Year=Year';

YearlyCost\_Solar=YearlyCost\_Solar';

AccumulatedCost\_Solar=AccumulatedCost\_Solar';

YearlyCost\_Generator=YearlyCost\_Generator';

AccumulatedCost\_Generator=AccumulatedCost\_Generator';

T = table(Year,YearlyCost\_Solar,AccumulatedCost\_Solar,YearlyCost\_Generator,AccumulatedCost\_Generator)

%

% Plot solar energy produced versus month

Energy\_Solar=N\_Panels\*(Ht.\*(1+alpha\*(Tamb-25))\*Eta\*Apanel);

bar(MonthNumber,Energy\_Solar)

hold on

plot(MonthNumber,Load\*ones(1,12),'r') % Display the load voltage on the plot

title({['\fontsize{12} Solar Energy Generated Per Month for Beta = ',...

 num2str(Beta\*180/pi),'^o'];['\fontsize{10} Latitude = ',...

 num2str(Latitude\*180/pi),'^o, Longitude = ', ...

 num2str(Longitude\*180/pi),'^o']},'FontWeight','Normal')

xlabel('Month')

ylabel('Energy in MJ')

legend('Solar Energy','Load')