

KKE/ESV – Solar and wind energy

Individual work – modelling solar and wind systems (template)

Software used: System Advisor Model (SAM)

Solar Water Heating (No Financial Model)

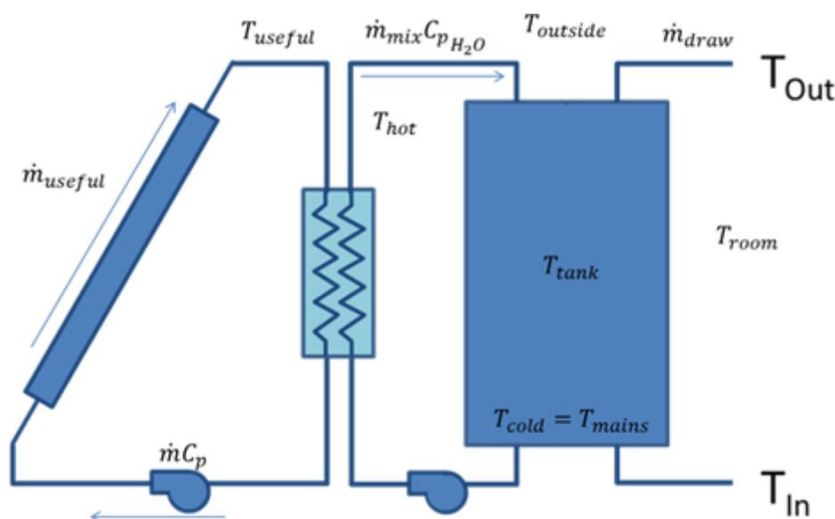
Introduction

The solar thermal collector converts solar radiation into thermal energy. Sunlight falls on the collector absorber, which is connected to the collector pipe. Energy transfer is ensured by heat transfer fluid that flows between the collector and heat exchanger (heat consumer), which is most often a solar tank, hot water tank or swimming pool. These collectors are usually located on the roof of houses, apartments, but also on administrative industrial buildings.

The basis of the collector is the absorption surface. A modern, powerful collector has this surface provided with a selective layer. In the case of the selective layer, the intake of thermal radiation is similar to that of a black body - there is no significant difference. However, the selective layer encloses the received energy and does not release it. There is a significant difference from the black body. Therefore, the stagnation temperature of a quality flat collector exceeds 200 °C, and of a vacuum collector it is even higher. The selective layer is applied to the absorption surface electrochemically in vacuum. Depending on the type of collector, the absorption surface is thermally insulated from its surroundings to prevent heat loss.

In the case of a vacuum/tubular collector, the thermal insulation is provided by a vacuum layer. The shape of the vacuum collector - the tube is determined by the design and technological possibilities of production. A circular (and relatively small) object - a tube, resists the ambient pressure much better than the flat, solid surface of the plate collector.

SAM models a closed loop which transfers solar energy from the working fluid to the water in an external heat exchanger. This setup is often used in climates where freezing temperatures occur, because the collector working fluid can be different than water. Water from the solar tank is typically used to preheat water in an auxiliary water tank and reduce the amount of heat needed to bring the delivered water to the set point desired by the user.



Location and Resource

This is a rooftop residential application. The application is intended to support the water heating of a family house located in Pilsen in the Czech Republic. The source weather file from the meteorological station Plzen-Mikulka is used.

Solar water, No financial

Location and Resource

Solar Water Heating

Grid Limits

Solar Resource Library

The Solar Resource library is a list of weather files on your computer. Choose a file from the library and verify the weather data information below.

You have not added any weather files to your library. To add files, use the download tools below to get weather files from the NSRDB, or click Add Remove Weather File folders to add files from your computer. The default library comes with only a few weather files to help you get started.

Filter: Name

Name	Latitude	Longitude	Time zone	Elevation	Station ID	Source
blythe_ca_33.617773_-114.588261_psmv3_60_tmy	33.61	-114.58	-8	82	258971	NSRDB
CZE_PK_Pizen-Mikulka.114500.TMYx.2004-2018	49.767	13.383	1	371.5	114500	ISD-TMYx
daggett_ca_34.865371_-116.783023_psmv3_60_tmy	34.85	-116.78	-8	561	91486	NSRDB
des_moines_ia_41.586835_-93.624959_psmv3_60_tmy	41.57	-93.62	-6	263	757516	NSRDB
ESP_AN_Sevilla.AP.083910.TMYx.2004-2018	37.4167	-5.8792	1	31	083910	ISD-TMYx
faermont_nz_46.9_-106.9_metro1_60_tmy	46.9	-106.9	-6	774	14014	TMY2

SAM scans the following folders on your computer for valid weather files and adds them to your Solar Resource library. To use weather files stored on your computer, click Add/remove Weather File Folders and add folders containing the files.

C:\Users\richt\SAM Downloaded Weather Files
Add/remove weather file folders...
Refresh library

Download Weather Files

The NSRDB is a database of thousands of weather files that you can download and add to your solar resource library: Download a default typical-year (TMY) file for most long-term cash flow analyses, or choose files to download for single-year or P50/P90 analyses. See Help for details.

☒ One location
☐ Multiple locations
☐ Legacy data (advanced)

Default TMY file
Download and add to library...

For locations not covered by the NSRDB, click [here](#) to go to the SAM website Weather Page for links to other data sources.

Weather Data Information

The following information describes the data in the highlighted weather file from the Solar Resource library above. This is the file SAM will use when you click Simulate.

Weather file: C:\SAM\2020.2.29\solar_resource\CZE_PK_Pizen-Mikulka.114500.TMYx.2004-2018.epw
View data...

Header Data from Weather File

Station ID: 114500

Latitude: 49.767 DD

Data Source: ISD-TMYx

Longitude: 13.383 DD

Elevation: 371.5 m

Time zone: GMT 1

For NSRDB data, the latitude and longitude shown here from the weather file header are the coordinates of the NSRDB grid cell and may be different from the values in the file name, which are the coordinates of the requested location.

Annual Averages Calculated from Weather File Data

Global horizontal: 3.05 kWh/m²/day

Average temperature: 9.5 °C

Direct normal (beam): 2.17 kWh/m²/day

Average wind speed: 3.0 m/s

Diffuse horizontal: 1.75 kWh/m²/day

Optional Data

*NaN indicates missing data.

The average annual total solar irradiation is 1113.25 kWh/m². The total irradiance during the year is shown in the following graph.

Solar Water Heating system

When determining the daily consumption of hot water, we use statistical data that the average daily water consumption per person in the Czech Republic is about 100 liters. This includes routine activities such as hygiene, toilets, laundry, food preparation, etc. If it is a household of two people, 200 kg of hot water is a relatively good estimate.

From theoretical assumptions, it is known that if the place is located in the northern hemisphere, then the collectors are oriented to the south, roughly at an inclination of 40 - 50 degrees. However, the best results can be obtained with small deviations. The optimal values were found by repeated simulation.

From the performed simulations it is evident that the collector system produces the most energy at azimuth of 190° (southwest) and at tilt of 40°. However, this does not mean that this is the optimal option. Because it is a year-round system, the ideal variant will be the one that produces the most energy in the winter, when our need for hot water is more significant. With regard to the total energy produced and the energy produced in the winter months, variant c) seems to be the most optimal variant.

a)
azimuth: 180°
tilt: 45°
total energy: 1561 kWh

Monthly Data ✕	
	System energy (kWh)
Jan	56.9769
Feb	86.433
Mar	113.714
Apr	187.492
May	192.32
Jun	194.741
Jul	201.307
Aug	194.907
Sep	153.294
Oct	99.5931
Nov	44.5658
Dec	36.1467

b)
azimuth: 185°
tilt: 45°
total energy: 1569 kWh

Monthly Data ✕	
	System energy (kWh)
Jan	57.4826
Feb	87.1688
Mar	113.935
Apr	187.754
May	192.982
Jun	194.807
Jul	201.606
Aug	195.19
Sep	154.985
Oct	101.625
Nov	44.8016
Dec	36.2008

c)
azimuth: 190°
tilt: 45°
total energy: 1571 kWh

Monthly Data ✕	
	System energy (kWh)
Jan	57.6904
Feb	87.5758
Mar	113.97
Apr	187.693
May	193.332
Jun	194.701
Jul	201.669
Aug	195.333
Sep	155.337
Oct	102.492
Nov	45.4493
Dec	36.2027

d)
azimuth: 190°
tilt: 40°
total energy: 1588 kWh

Monthly Data ✕	
	System energy (kWh)
Jan	56.6037
Feb	85.982
Mar	115.238
Apr	190.471
May	197.371
Jun	199.487
Jul	205.37
Aug	198.762
Sep	156.713
Oct	102.053
Nov	44.3122
Dec	35.4992

e)
azimuth: 190°
tilt: 50°
total energy: 1545 kWh

Monthly Data ✕	
	System energy (kWh)
Jan	58.4573
Feb	88.1827
Mar	112.143
Apr	183.947
May	188.311
Jun	188.732
Jul	196.726
Aug	190.958
Sep	153.445
Oct	102.196
Nov	45.7059
Dec	36.4844

f)
azimuth: 190°
tilt: 55°
total energy: 1552 kWh

Monthly Data ✕	
	System energy (kWh)
Jan	60.0642
Feb	90.7787
Mar	114.239
Apr	185.728
May	188.931
Jun	183.794
Jul	192.427
Aug	191.595
Sep	155.357
Oct	104.837
Nov	47.1627
Dec	37.5151

Due to the fact that it is a year-round installation and the conditions in the Czech Republic, which is exposed to both hot summer days with plenty of sunlight and cold winter days with a lack of radiation, the most optimal variant is a tubular vacuum collector with the best year-round efficiency. Due to its availability in the Czech Republic, a solar collector from Vaillant was chosen. When choosing, it is also necessary to take into account the area of the collector with respect to the available area and the coefficients for optical gain and heat loss. Therefore, a collector called Vaillant Solar Systems Inc auroTHERM 1140 2 VTK 1140 2 was chosen.

The collector datasheet is available for example here:

<https://www.vaillant.co.uk/for-installers/products/aurotherm-exclusive-vtk-570-discontinued-3137.html#downloads>

It is possible to obtain flow data from the datasheet. The minimum flow is 180 l/h (0.05 kg/s). If it is higher, the pressure drop will start to increase. Assume the use of two collectors that are connected in series. Year-round operation requires the use of antifreeze fluid (Glycol). Because heat collectors also work with diffuse radiation, the sky diffuse model calculates values of the components of the sky diffuse irradiance (isotropic, circumsolar, and horizon brightening). The Perez model uses a more complex computational method than the other two methods that accounts for both isotropic and circumsolar diffuse radiation, as well as horizon brightening. Beam and diffuse radiation are available in the weather file, so they are selected as irradiance inputs. There is green grass around the building, so albedo 0.2 is chosen.

Hot Water Draw
Hourly hot water draw profile kg/hr
Total annual hot water draw kg/year
Scale draw profile to average daily usage ☒
Average daily hot water usage kg/day

System
Tilt deg
Azimuth deg
Total system flow rate kg/s
Working fluid
Number of collectors
Diffuse sky model
Irradiance inputs
Albedo 0.1
Total system collector area m²
Rated system size kW
-Shading
Shading losses
-System Availability
 Constant loss: 0.0 %
Hourly losses: None
Custom periods: None

Collector
☐ Enter user-defined parameters
☒ Choose from library
User-defined collector:
Collector area m²
FRta
FRUL W/m².C
Incidence angle modifier
Test fluid
Test flow kg/s
Filter: Name

Name	SRCC Number	Type	Area	IAM	FRta	FRUL	Test Fluid	Te
Vaillant Solar Systems Inc. Vaillant Solar Systems VFK 125	2009115A	Glazed Flat-Plate	2.51	0.13	0.684	4.52	0	0.0
Vaillant Solar Systems Inc. auroTHERM 570 2 VTK 570 2	2010009B	Tubular	1.15	0.03	0.554	0.81	0	0.0
Vaillant Solar Systems Inc. auroTHERM 1140 2 VTK 1140 2	2010009A	Tubular	2.28	0.03	0.554	0.81	0	0.0
VELUX America Inc. VELUX CLI U12 4000	2007018A	Glazed Flat-Plate	2.51	0.02	0.686	2.69	0	0.0
VELUX America Inc. VELUX CLI S06 4000	2007018B	Glazed Flat-Plate	1.42	0.02	0.651	2.65	0	0.0
VELUX America Inc. VELUX CLI M08 4000	2007018C	Glazed Flat-Plate	1.16	0.02	0.63	2.61	0	0.0
Viessmann Manufacturing Company (US) Inc. Vitosol 100-F SV1 SH1	2007042A	Glazed Flat-Plate	2.49	0.1	0.769	3.61	0	0.0
Viessmann Manufacturing Company (US) Inc. Vitosol 200-F SV2 SH2	2005019A	Glazed Flat-Plate	2.52	0.07	0.716	3.06	1	0.0
Viessmann Manufacturing Company (US) Inc. Vitosol 200-T SD2A -3m2	2008025B	Tubular	4.34	-0.0	0.547	1.15	0	0.0

Solar Tank and Heat Exchanger
Solar tank volume m³
Solar tank height to diameter ratio
Solar tank heat loss coefficient (U value) W/m².C
Solar tank maximum water temperature C
Heat exchanger effectiveness 0.1
Outlet set temperature C
Mechanical room temperature C

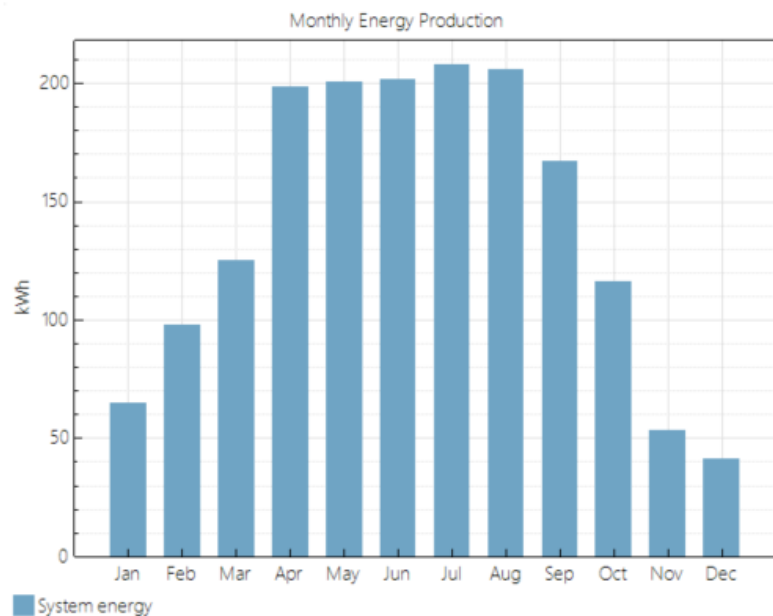
Piping and Pumping
Total piping length in system m
Pipe diameter m
Pipe insulation conductivity W/m.C
Pipe insulation thickness m
Pump power W
Pump efficiency 0.1

Advanced
Use custom mains profile ☐
Hourly custom mains profile C
Use custom set temperatures ☐
Hourly custom set temperatures C

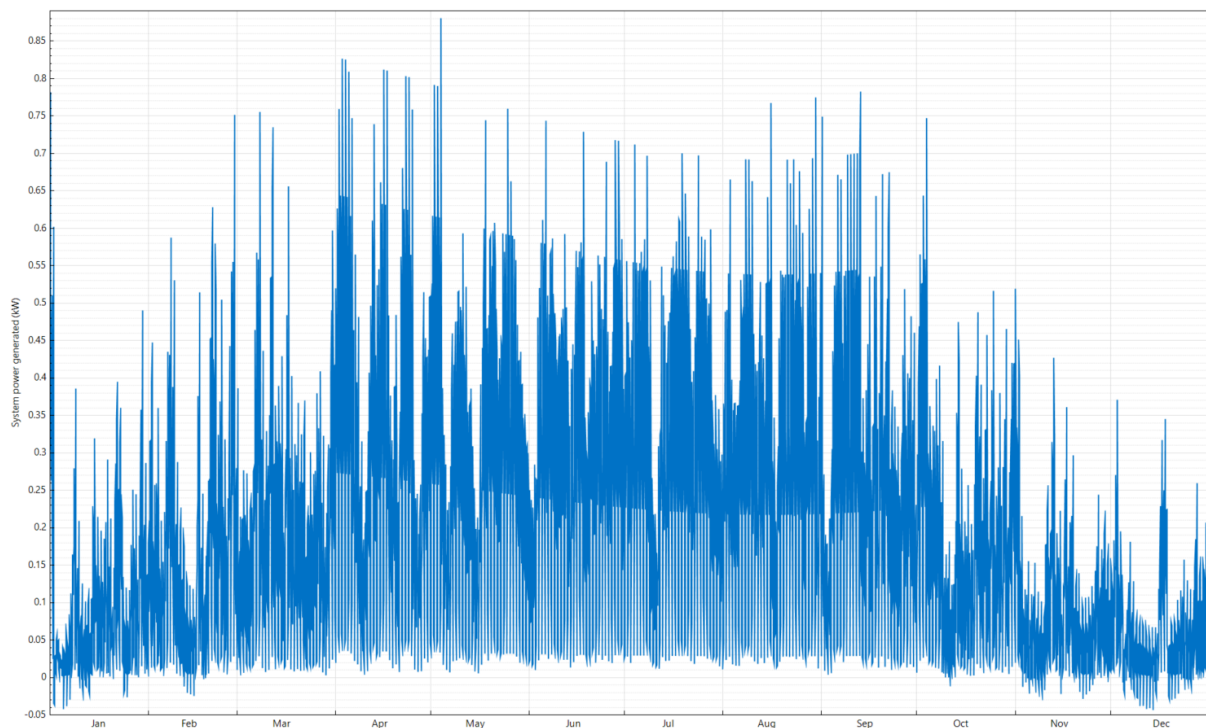
Simulation

The simulation is performed according to the attached screenshot. The energy produced, or the saved electricity, which would normally be used for electric heating and the monthly production, is shown in the following figure.

Metric	Value
Annual energy saved (year 1)	1,680 kWh
Solar fraction (year 1)	0.47
Aux with solar (year 1)	1,748.6 kWh
Aux without solar (year 1)	3,576.7 kWh
Capacity factor (year 1)	7.9%



The power generated during the year is shown in the following figure.



The possibilities of increasing the power output can be found in the choice of a more powerful collector, but this usually happens at the expense of the price. If more space and funding were available, a third collector could be added. Using a more efficient heat exchanger and pump would also increase performance. Options are also offered by piping, the length of which increases the pressure drop, so shorter piping would mean higher performance. In addition, if the pipes were better thermally insulated, we would get more heat. Heat losses are also affected by its width.