Carl von Ossietzky
Universität
Oldenburg

Domestic Hot Water Supply in northern regions of India

Renewable Energy Heat
Winter Semester 23/24

Mubas Koran Kunnan,
Vishnu Vezhakkattu Ranganathan,
Gokul Unnikrishnan

25.01.2023

Motivation

- India's ranking as the third-largest global energy consumer underscores its economic vitality, necessitating a robust and reliable energy infrastructure.
- Recent challenges, notably an electricity crisis triggered by a coal shortage affecting over 150 power plants, highlight the vulnerability of the current energy system and the need for diversified, resilient solutions.
- The government's ambitious target of achieving 100 gigawatts (GW) of solar energy capacity by March 2023 signifies a visionary commitment to sustainable, eco-friendly power sources.
- The cold climate prevalent in northern regions, combined with abundant solar irradiance, offers a strategic opportunity to harness solar energy for Domestic Hot Water Systems (DHWS) and reduce reliance on conventional energy sources.

Location

- Dharamshala,Himachal pradesh, India, Latitude: 32.215° N Longitude: 76.320° E Elevation : 1312 m

Figure 1 : https://theframes.in/traveling/uncover-the-hidden-gems-of-dharamshala

Environmental Conditions

Month	Irradiation(kwh/m2)
January	145.54
February	187.76
March	176.03
April	186.82
May	182.8
June	166.36
July	137.03
August	107.69
September	175.32
October	215.35
November	170.18
December	186.31

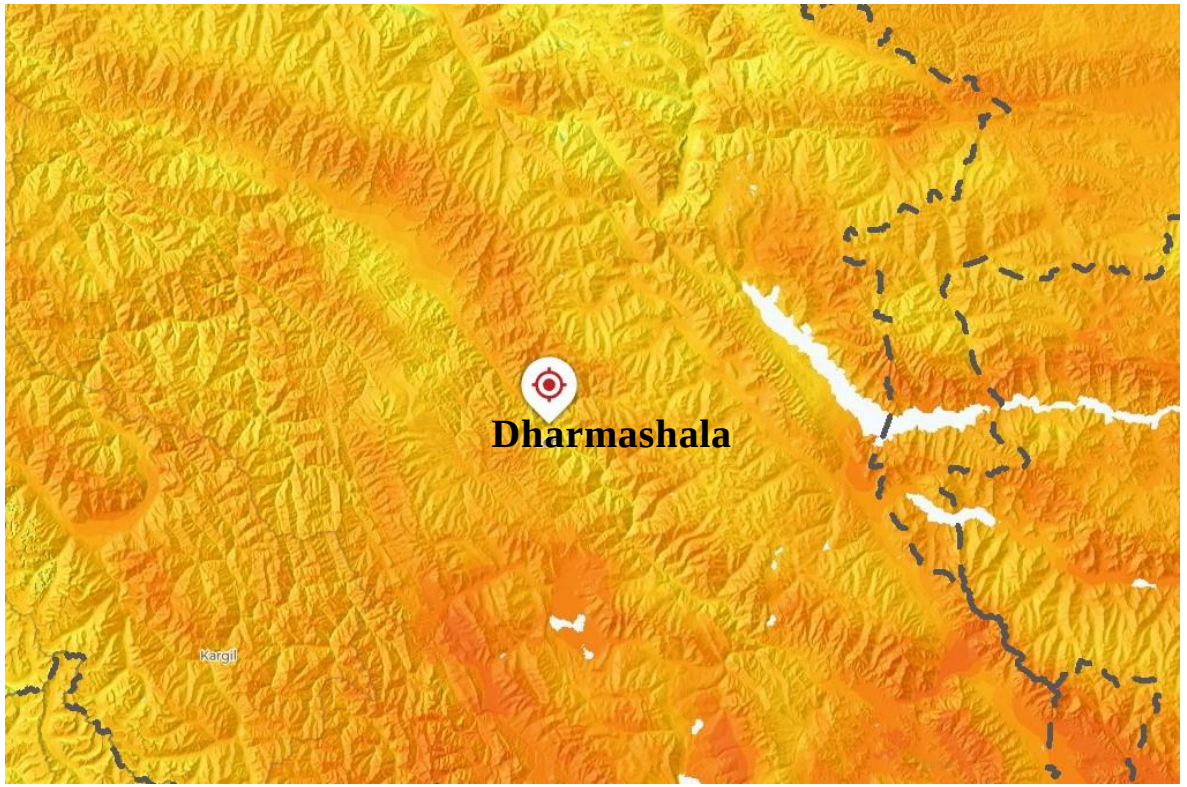
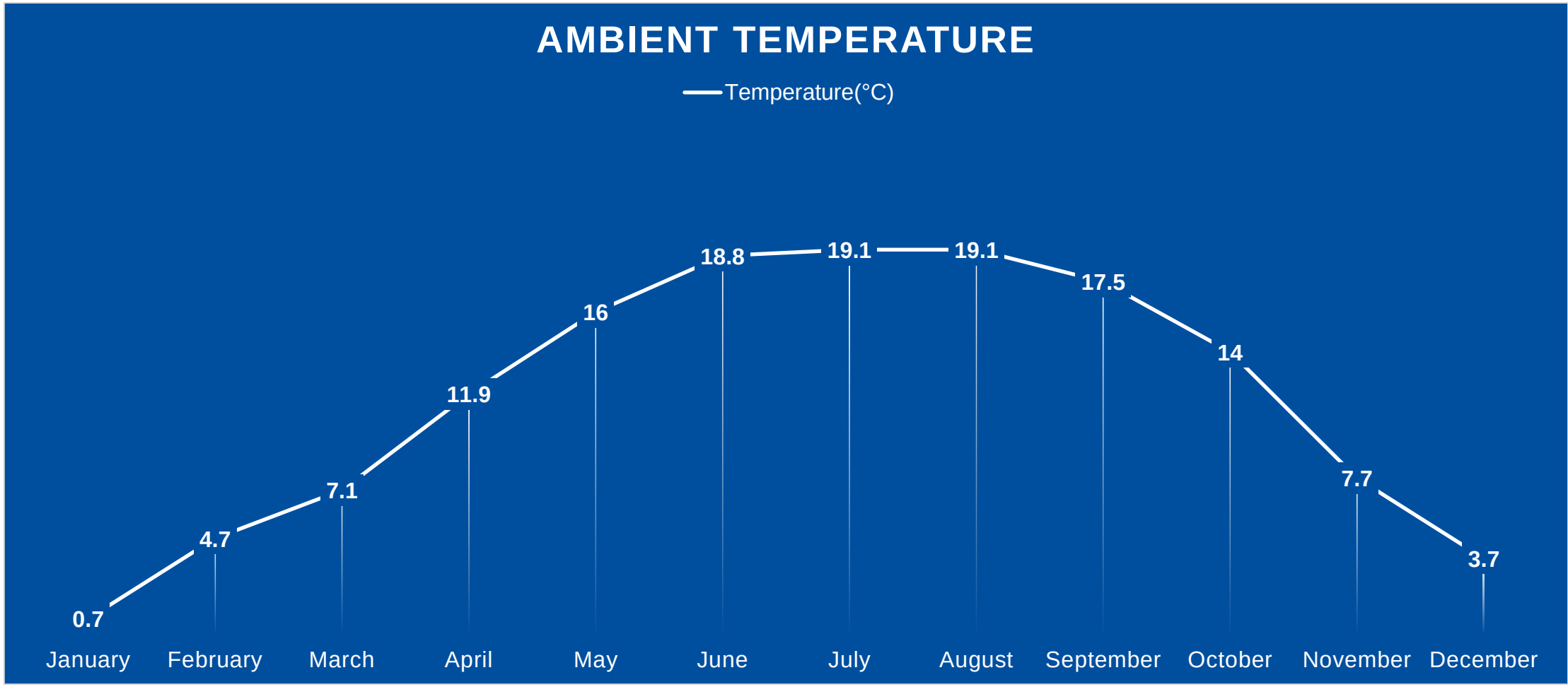


Figure 2 : *Solar Keymark* n.d., www.duurzaamloket.nl, viewed 25 January 2024, <https://www.duurzaamloket.nl/SolKey_X014/>.

Table 2 European Commission 2022, *JRC Photovoltaic Geographical Information System (PVGIS) - European Commission*, re.jrc.ec.europa.eu.

Environmental Conditions



Graph 1 European Commission 2022, *JRC Photovoltaic Geographical Information System (PVGIS) - European Commission*, re.jrc.ec.europa.eu.

Energy Demand

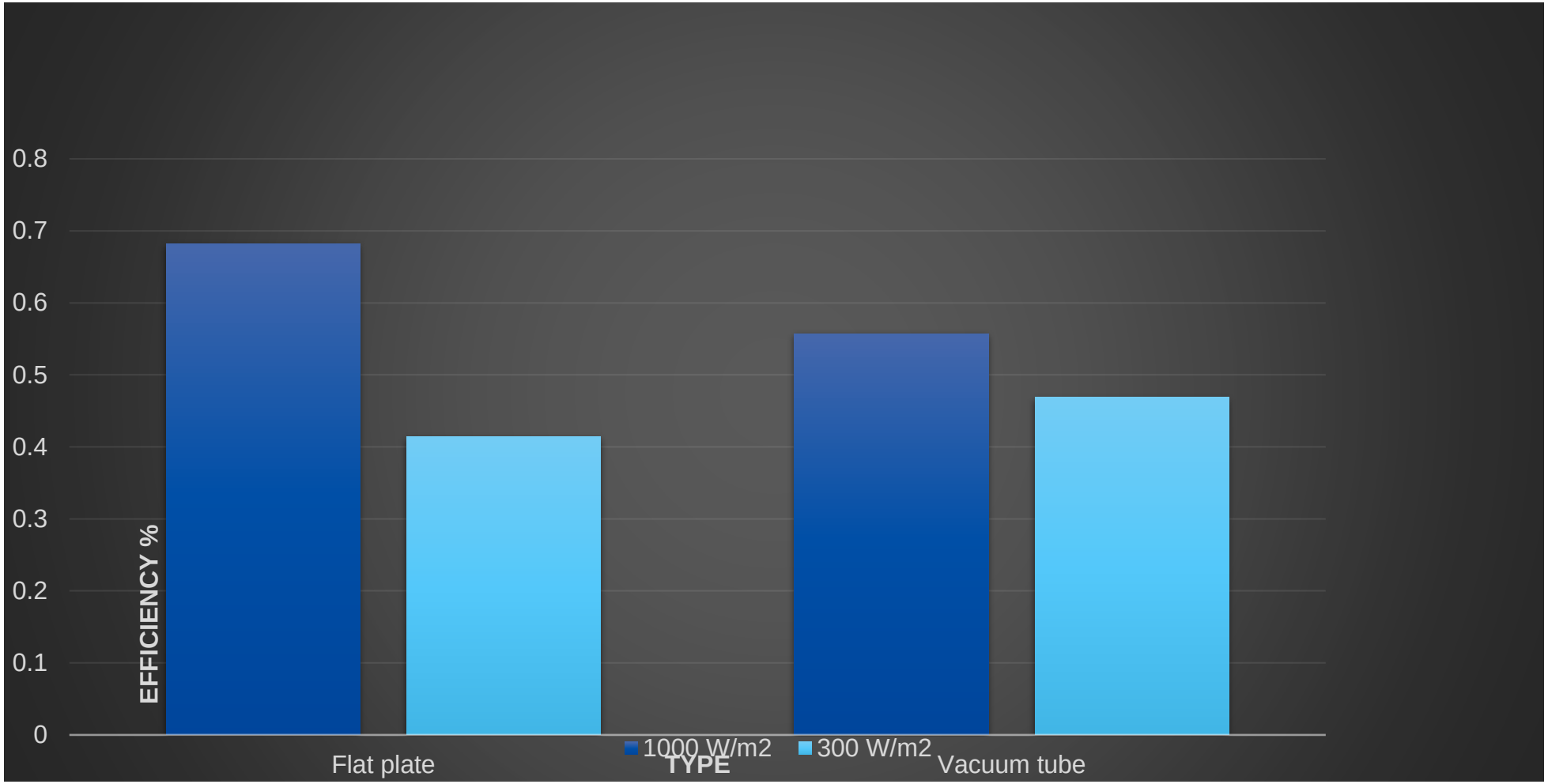
- Demand for Person : 50 litter per day
- Number of Person per house : 5
- Demand : 5*50 = 250 litter per day
- Temperature Demand : 50°C
- The equation

$$Qdem = m.\ Cp.\ \Delta T$$

Months	Energy Demand (kW/h)
January	444.26
February	368.71
March	386.58
April	332.25
May	306.38
June	272.08
July	278.45
August	278.45
September	283.42
October	324.41
November	368.88
December	417.22

Table 1

SOLAR COLLECTOR



Graph 2

Solar collector efficiency

$$\eta_{coll} = \eta_0 - c_1 \frac{T_m - T_a}{G_T} - c_2 \frac{(T_m - T_a)^2}{G_T}$$

Collector Type	η_0	c_1 [W/(mK)]	c_2 [W /(mK^2)]
Flat plate (Sunnex SA)	0.716	3:35	0.012
Vacuum tube (Bosch Buderus)	0.595	0.90	0.05

Table 3 : http://www.solarkeymark.nl/DBF/

Description of Collector

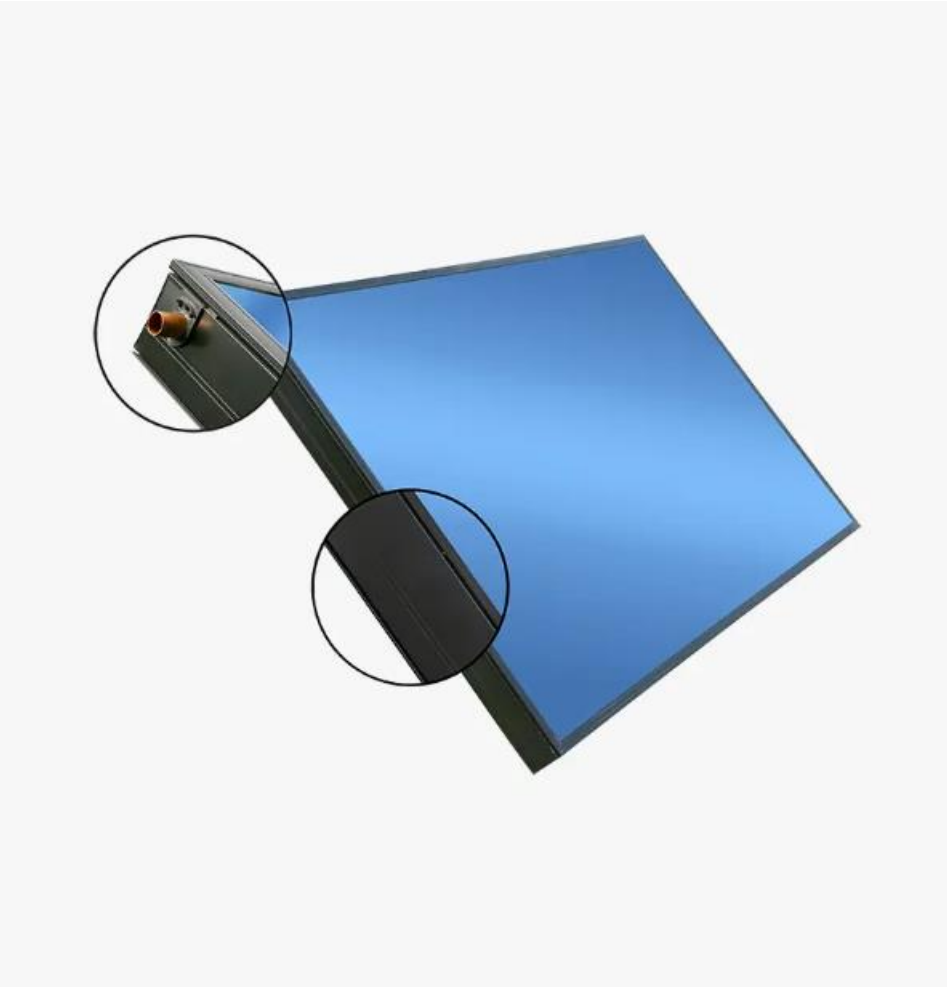


Figure 3 : https://www.sunex.pl/angebot/sonnenkollektoren/flachkollektoren/kolektory-plaskie-sx.html

Company: Sunnex S.A.
Model : Basicx 2.0 4C

- Flat plate collector
- Gross area: 2,02 m^2
- Zero Loss efficiency $\eta 0$: 0.716
- Flow Rate : 0.014 kg/s
- Fluid : Water + Glycol
- Heat Loss Coefficients
  - a_{1a}: 3,35 $W/(m^2K)$
  - a_{2a}: 0,012 $W/(m^2K^2)$

Assumptions and Considerations

- Heat exchanger Effectiveness is 1. (Collector Heat exchanger correction factor $F'\ R\ /FR = 1$)

- Constant demand

- Collectors with Azimuth 0°

- Two-cover collector

- Absorptance and transmittance product, $(\tau\alpha)\ /(\tau\alpha)n = 0.94$

F-chart method

$$f = 1.029Y - 0.065X - 0.245Y^2 + 0.0018X^2 + 0.0215Y^3$$

$$X = F_R U_L \frac{\bar{F}_R}{F_R}.(T_{ref} - \bar{T}_a).\Delta T \frac{A_c}{L}$$

$$Y = F_R(\tau\alpha)_n \frac{\bar{F}_F}{F_F} \frac{(\bar{\tau}\alpha)}{(\tau\alpha)_n} \bar{H}_T N \frac{A_C}{L}$$

$$F_R U_L = F_{av} U_L \left(1 + \frac{A_{c1} F_{av} U_L}{2mc_p}\right)^{-1}$$

$$F_R(\tau\alpha)_n = F_{av}(\tau\alpha)_n \left(1 + \frac{A_{c1} F_{av} U_L}{2mc_p}\right)^{-1}$$

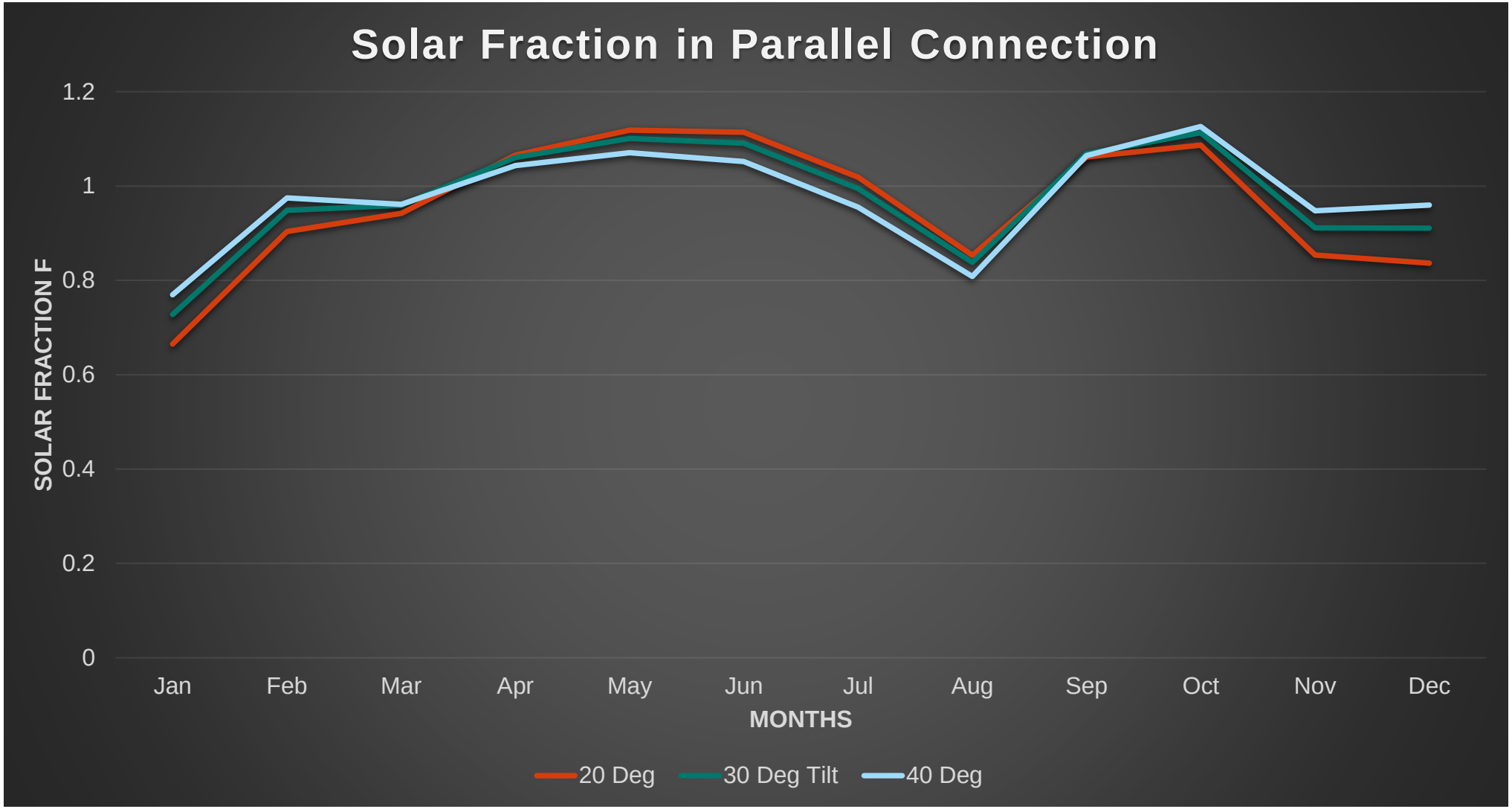
Month	X	Y	f
Jan	5.468931	1.515049	0.769743
Feb	5.712087	2.12714	0.974646
Mar	5.879746	2.105817	0.961258
Apr	6.27843	2.516458	1.043429
May	6.708115	2.759234	1.070598
Jun	7.066455	2.736438	1.052325
Jul	7.1087	2.275875	0.955212
Aug	7.1087	1.788579	0.808601
Sep	6.892404	2.768467	1.064677
Oct	6.486286	3.069967	1.126136
Nov	5.924633	2.064712	0.947468
Dec	5.64736	2.065125	0.959836

Table 4

X: Ratio of absorbed solar radiation to heating loads

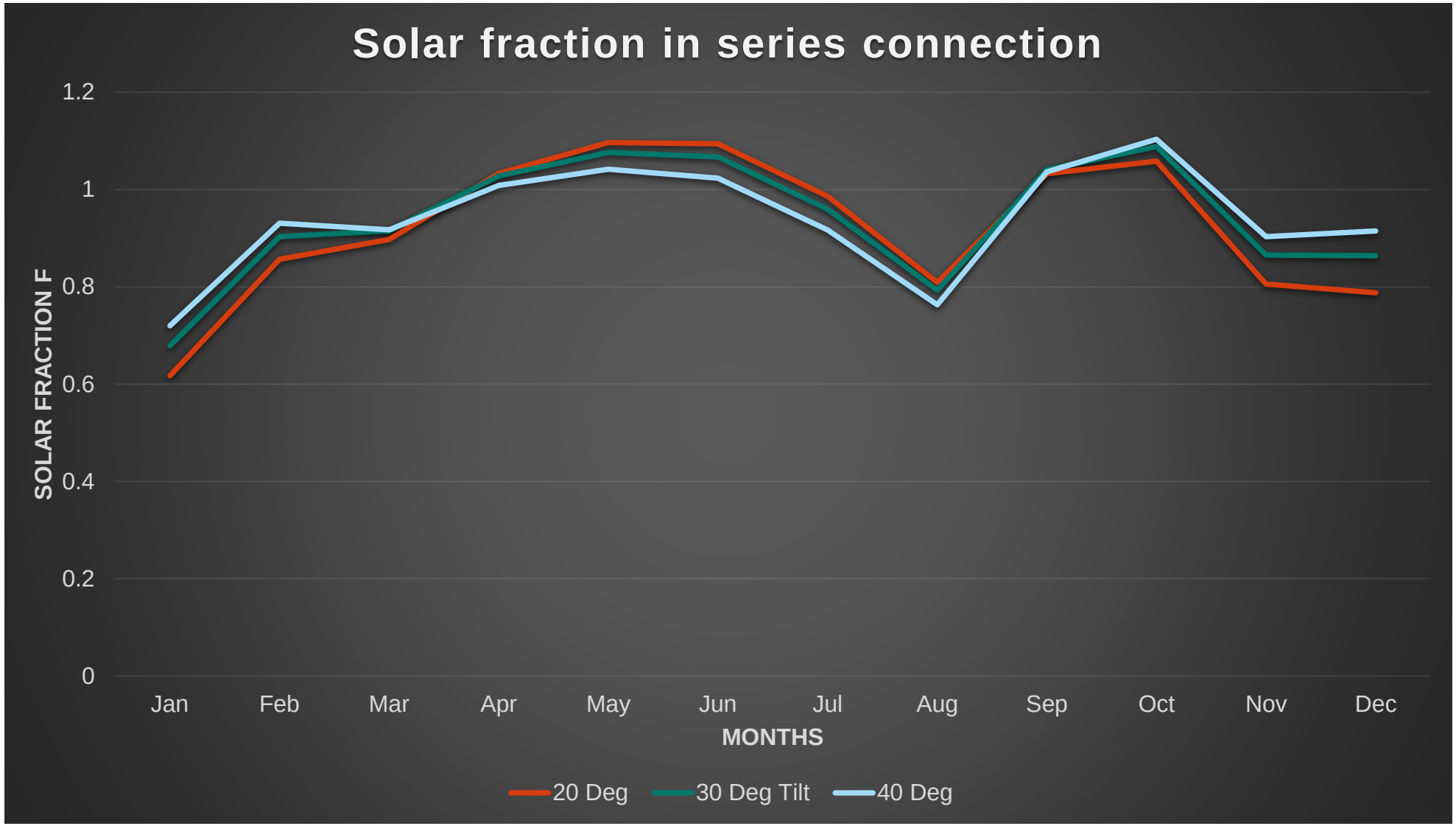
Y: Ratio of collector losses to heating loads

F-chart Parallel



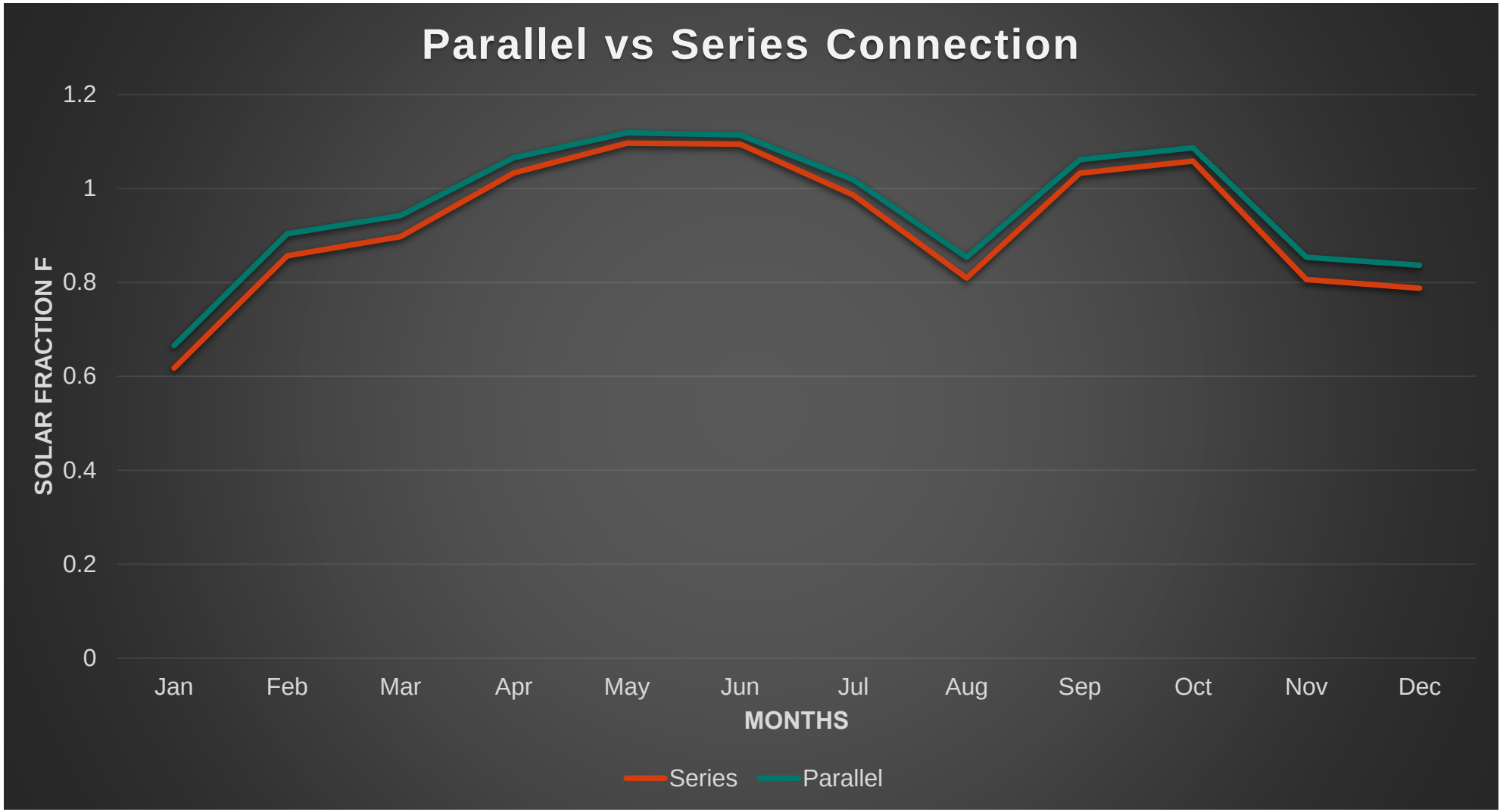
Graph 3

F- chart Series



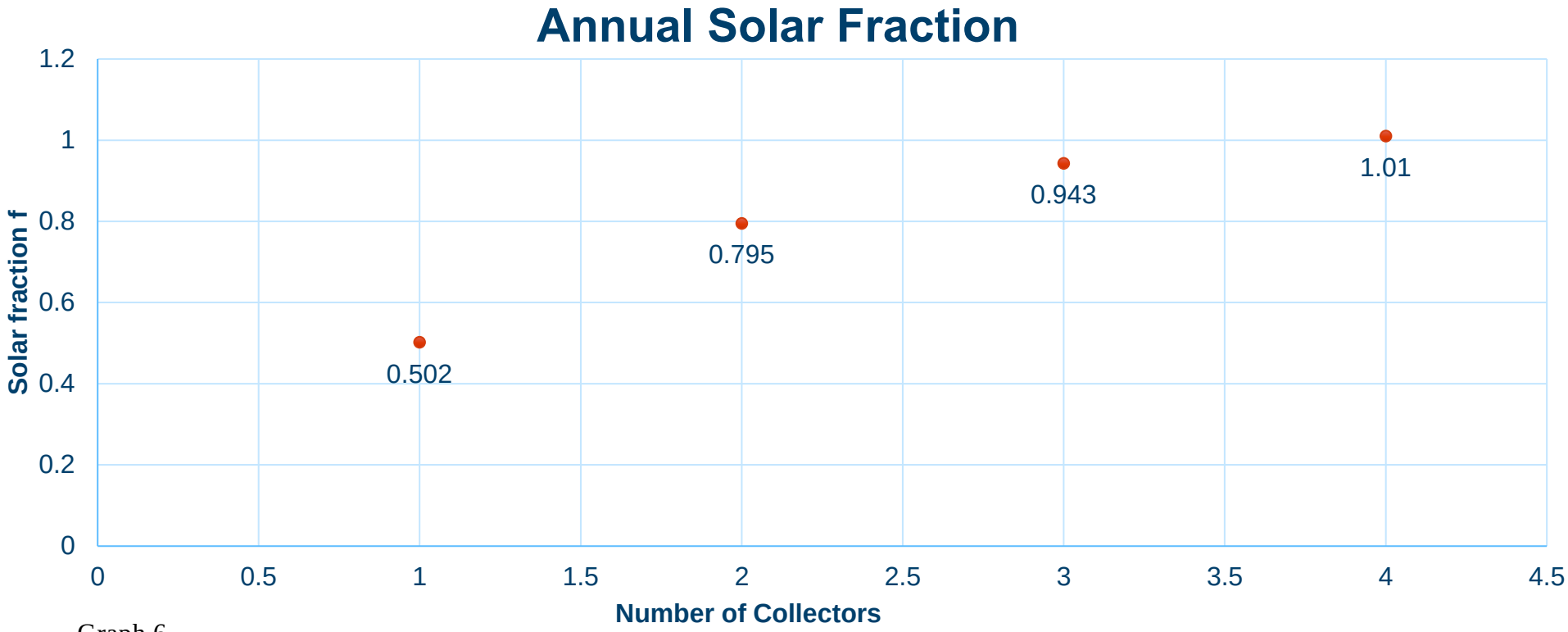
Graph 4

Parallel and Series Connection



Graph 5

Results



Graph 6

No: of collectors = 3

Total collector area : **6,06 m²**

Average annual solar fraction

- **f= 0.943, for parallel**
- f = 0.905, for series

Desired connection: parallel

System Layout

Brand : Sunnex S.A.

Model : Basicx 2.0 4C

- **Number of collector : 3**
- **Preferred angle of tilt : 40^0**
- **Connection configuration : Parallel**
- **Storage tank capacity: 300 L**
- **Utilization : 670.14 $kWhm^{-2}$**
- **Calculated efficiency : 31.93%**

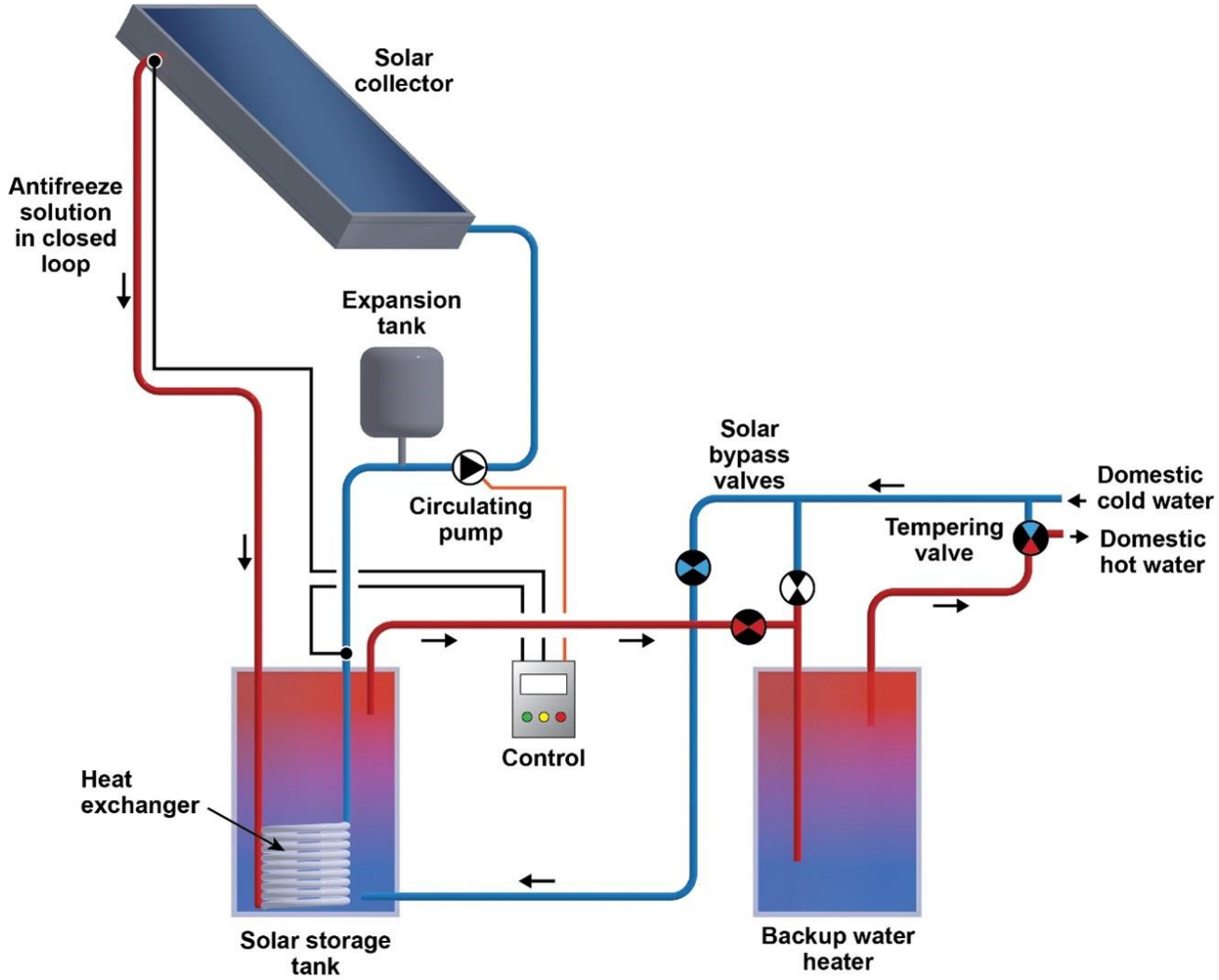


Figure 4 : https://www.pnnl.gov/projects/om-best-practices/solar-water-heating-systems

Conclusion

- We formulated the design of a residential solar hot water system employing the F-chart method. This method allowed us to forecast outcomes considering various factors, including system design and losses, under diverse weather conditions.
- The values for tilt angles and irradiance were acquired using the PVGIS tool.
- Ultimately, we determined the optimal tilt angle, utilizing the F-chart method, to achieve the highest solar fraction.
- Additional analysis can be conducted to assess the effectiveness of the heat exchanger and explore measures aimed at preventing bacterial growth in the storage tank.

Carl von Ossietzky
Universität
Oldenburg

Reference

- European Commission 2022, *JRC Photovoltaic Geographical Information System (PVGIS) - European Commission*, re.jrc.ec.europa.eu.
- *INDEX: 151 101 520 FLACHKOLLEKTOR AMP 2.0 AMP 2.0* n.d., viewed 25 January 2024, <https://www.kamdi24.de/media/files/datenblatt/Produktdatenblatt_AMP%202.0.pdf>.
- *Solar Keymark* n.d., www.duurzaamloket.nl, viewed 25 January 2024, <https://www.duurzaamloket.nl/SolKey_X014/>.
- *Solar Water Heating Systems | PNNL* n.d., www.pnnl.gov.
- Vivan, M n.d., *Uncover the Hidden Gems of Dharamshala: Must-Visit Tourist Places for Travel Enthusiasts*, theframes.in, viewed 25 January 2024, <https://theframes.in/traveling/uncover-the-hidden-gems-of-dharamshala>.