Research, Education and Green Campus

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Queen Mary University of London

13th May 2022

Research in Sustainable Thermal System Lab

- Two-phase flow heat transfer and heat transfer enhancement
- Design of heat exchangers: condensers and evaporators
- Sustainable thermal energy systems e.g. (1) Solar Hot Water, Solar-Assisted Heat Pump Heating System; (2) Magnetic Refrigeration; (3) Organic Rankine Cycle for Recovering Low Temperature Thermal Energy.
- Building energy efficiency, Intelligent building
- Advanced cooling technologies e.g. Thermal Management of Batteries; Thermal management of Data Centre.

Current Teaching

- **DEN438/DENM035 Renewable Energy Sources, 4th year MEng and MSc students**

- **DEN5208 Heat Transfer and Fluid Mechanics, 2nd Year Mechanical Eng. Students**

- **DEN6208 Advanced Heat Transfer and Fluid Mechanics, 3rd year and MSc students**

- **EMS450U Exploring Mechanical Engineering – Case Study 2, 1st year Mech. Eng.**

- **Projects: Third-year projects, MEng projects, MSc projects**

Current Teaching

- **DEN438/DENM035 Renewable Energy Sources, 4th year MEng and MSc students**

- **This module covers building energy efficiency, renewable energies of solar, wind, hydro, tidal, wave, geothermal sources and technologies of heat pump, ORC, wind turbine, photovoltaic, fuel cell and hydrogen etc, focusing on resource, technology, economic, environmental and social impacts.**

- **Coursework:** ***Design and analysis of a sustainable energy application***

Support to *Field trip* to energy systems on Mile End campus

DEN438/DENM035 Renewable Energy Sources module since 2014

- Boiler heating system for Queens' building
- Boiler heating and ventilation system for Joseph Priestley building
- Air conditioning system for Francis Bancroft building
- Ground source heat pump system for Art II
- Combined heat and power system
- Photovoltaic system and its grid integration at Library
- PV panel at Biology building
- BMS

Many thanks to: Philip Tamuno, Liudmyla Pasichnichenko, Timothy Lee, Glyn Lee, Richard Frost, Neil Florey etc

Support to *Field trip* to energy systems on Mile End campus

16 Nov 2021

Students feedback:

The tour of the renewable energy technologies in the QMUL estate was genuinely interesting and informative.

Support to *Third-year* research projects

Third year projects:

- Claudio Luchetti, *Assessment of Carbon dioxide emission of electrically heated students residence halls*, 2011-2012
- Rodney Senkezi, Analysis of the performance of gas-fired condensing boilers, 2011-2012
- Nicolas Philippe-Desneufbourgs, Analysis of the energy performance of a ground source heat pump at QMUL, 2011-2012
- Abdulraouf Gandi, Solar thermal absorption cooling systems, 2011-2012
- Arouge Agha, Micro solar absorption system, 2013-2014
- Tsu May Lim, Portable absorption chiller, 2016-2017
- Luis Jacobo Pavia Palmlof, Sorption based atmospheric water generation by solar energy in arid regions, 2020-2021
- Hamza Allamki, Optima; sizing and analysis of hybrid renewable energy systems for Jazirat Al Hillaniyyah, 2020-2021
- Niweithan Nicholas Jeyachristy, Life Cicle Analysis of a sustainable heating system driven by solar energy, 2021-2022

Support to *MEng* and *MSc* research projects

MEng project:

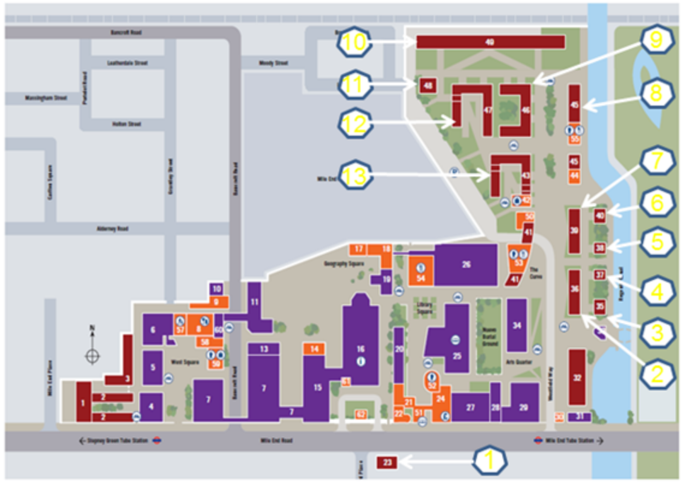
- Shaun Das, Yasin Allyjam, Vinod, Junaid, Ade; *Energy audit of Engineering building*, 2007-2008

MSc projects:

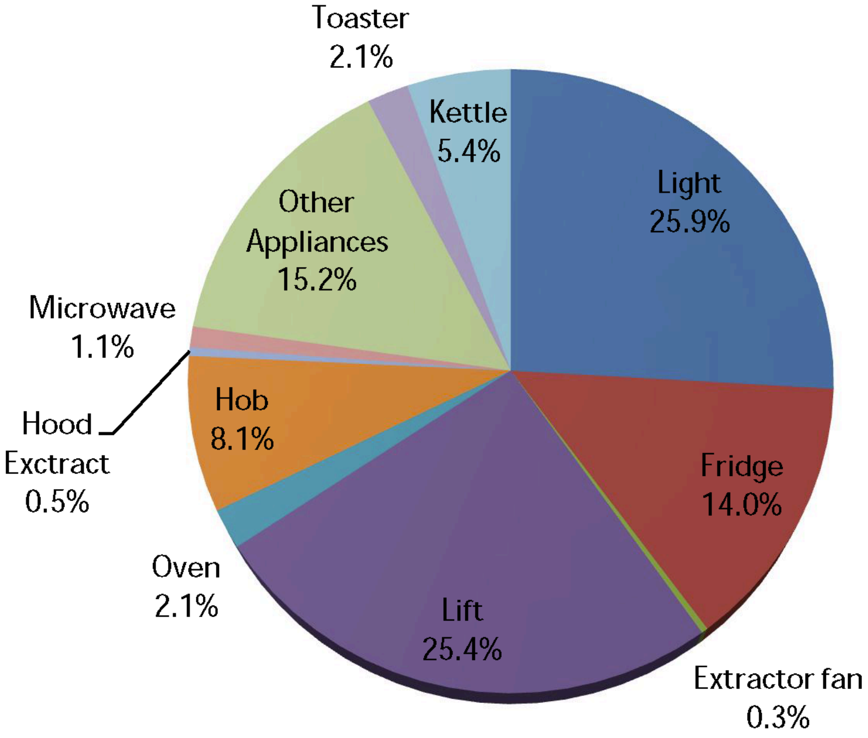
- Li Xu, Feasibility study of BIPV and simulation using Energy Plus, 2010-2011
- Yusuf Kerem Angun, Energy audit of Joseph Priestley building, 2012-2013
- Tayyaba Waqar, Energy management by scheduling automation, 2013-2014
- Yigit Duveroglu, Design of a domestic compound parabolic concentrator, 2017-2018
- Kentas Warith Partono, Feasibility study on potential of tidal power plant in Nusa Penida Island, Bali, Indonesia, 2017-2-18

3rd year projects

- **Assessment of Carbon Dioxide Emission of Electrically Heated Student Residence Halls (2011-2012)**



1. Lindop House
2. Maynard House
3. Chapman House
4. Chesney House
5. Lodge House
6. Selincourt House
7. Varey House
8. France House
9. Creed House
10. Pooley House
11. Lynden House
12. Maurice Court
13. Beaumont Court

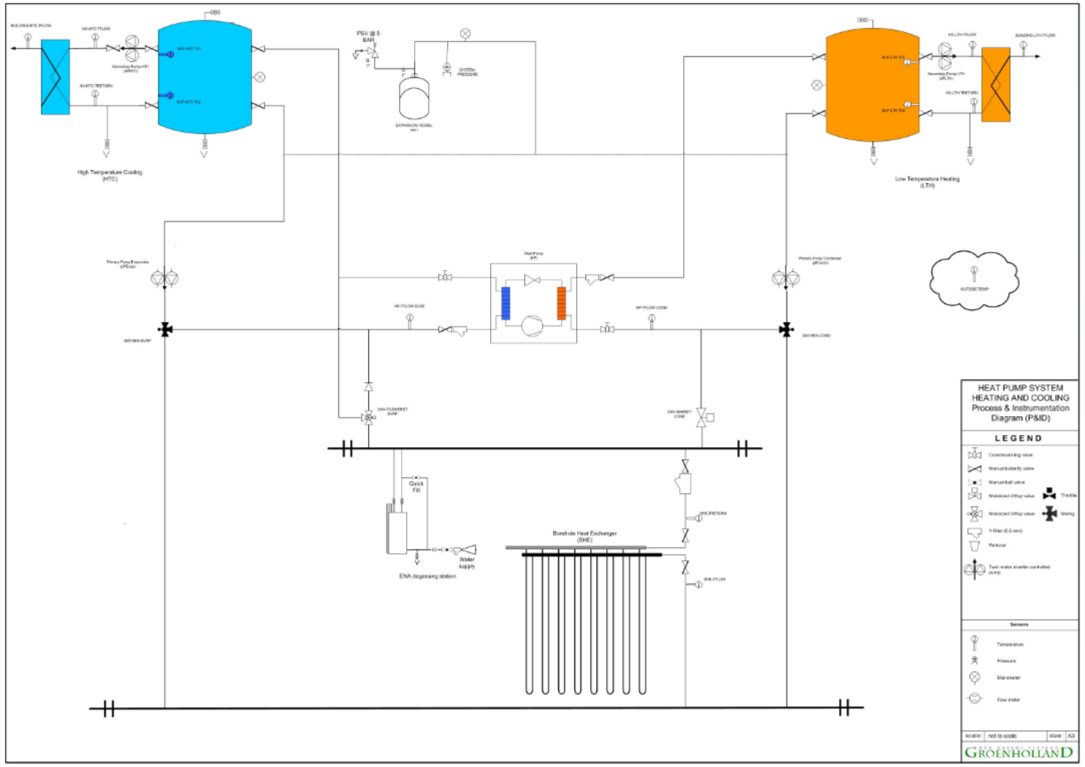


Varey House: energy usage breakdown excluding heating and how water

Building	Floor Area	Electricity		Fossil fuel		TOTAL
	m²	kWh/ year	$kgCO_2/m^2/$ year	kWh/ year	$kgCO_2/m^2/$ year	$kgCO_2/m^2/$ year
Pooley House	4,508	704,934	82.0	482,83	1.97	84.0
France House	4,216	416,844	51.9	233,87	1.02	52.8
Varey House	3055.48	378,782	65.0	394,960	23.7	88.7
Maynard House	3055.48	405,037	69.5	314,960	18.9	88.4
Beaumont House	3886.63	258,829	34.9	311,05	1.47	36.4
Maurice Court	4360.96	330,862	39.8	198,39	0.835	40.6
Creed Court	2850.91	243,817	44.8	181,11	1.17	46.0
Lindop House	1,406	146,331	54.6	158,086	20.6	75.2

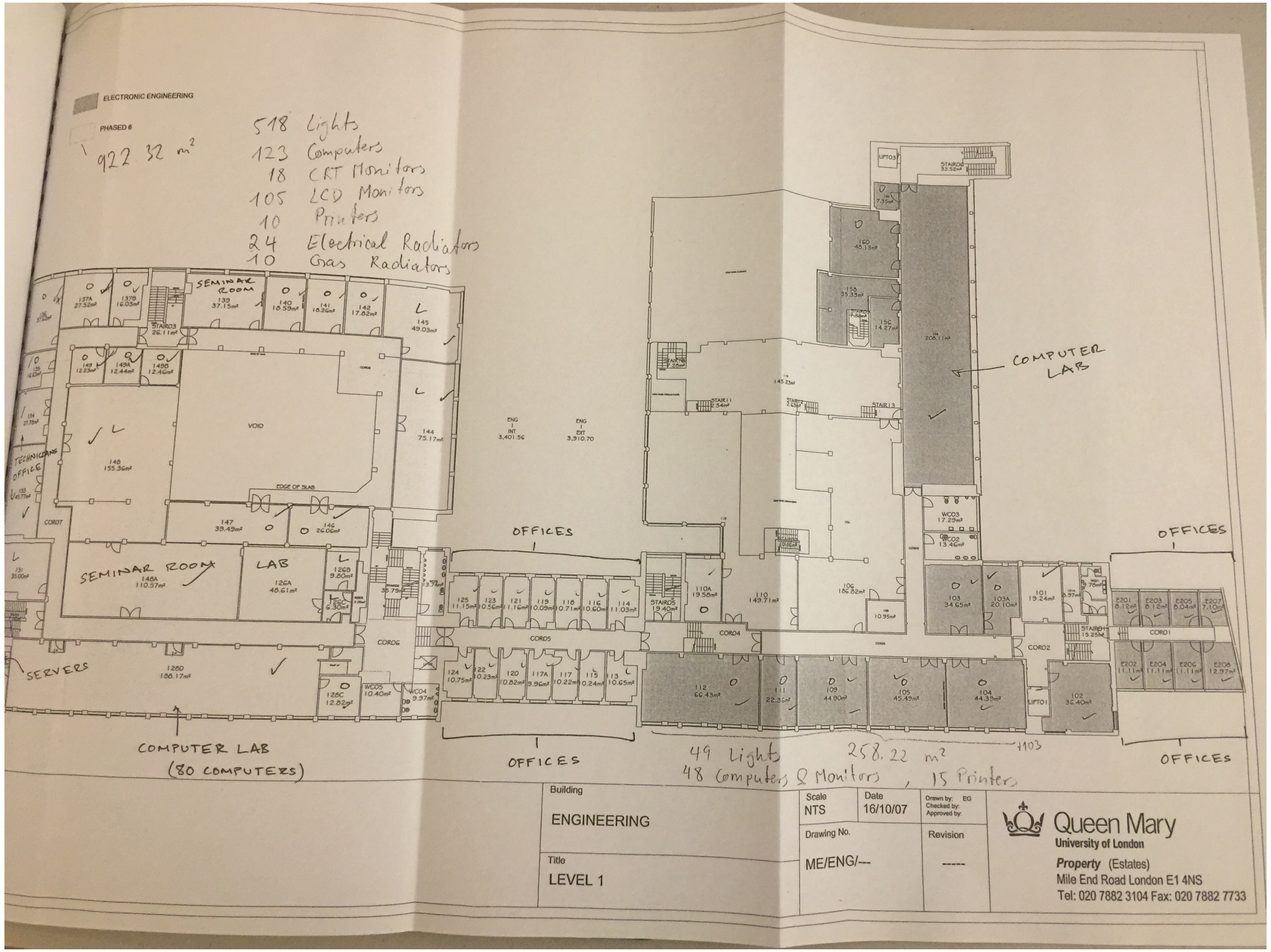
3^{rd} year projects

- **Investigation of ground source heat pump system for ART II (2011-2012)**



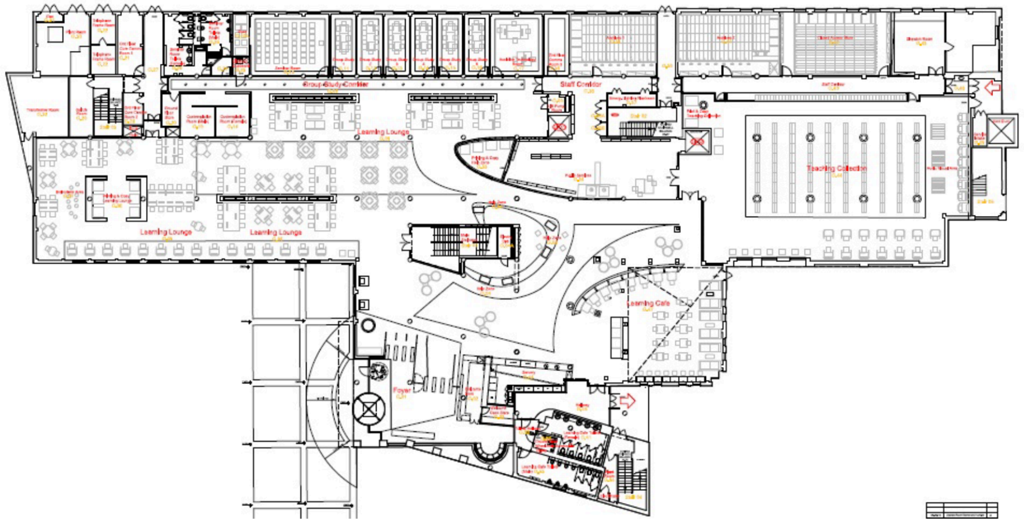
4th year MEng projects

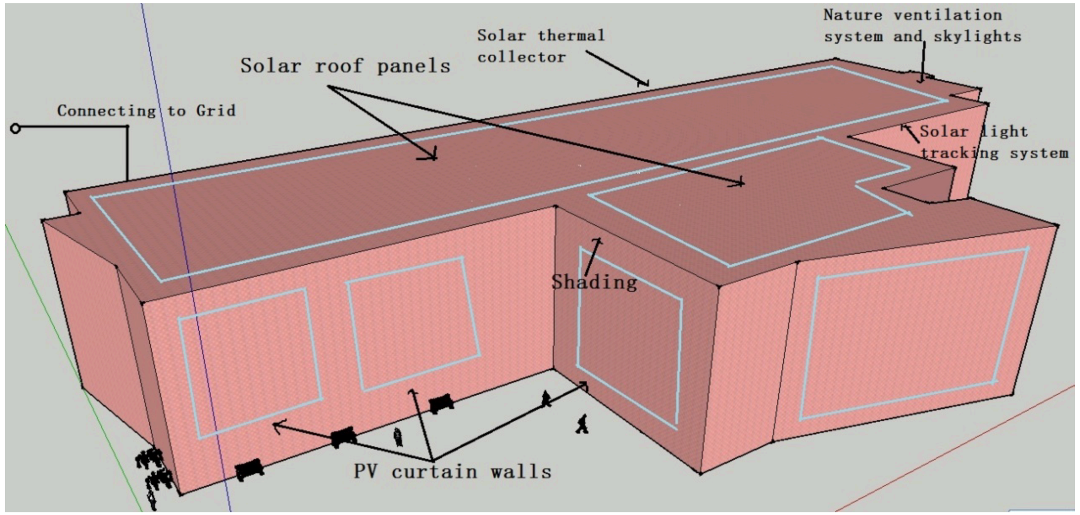
- **Energy audit of Engineering building, 2007-2008 (Shaun Das, Yasin Allyjam, Vinod, Junaid, Ade)**



MSc projects

- **Feasibility study of BIPV and simulation using Energy Plus, 2010-2011 (Li Xu)**





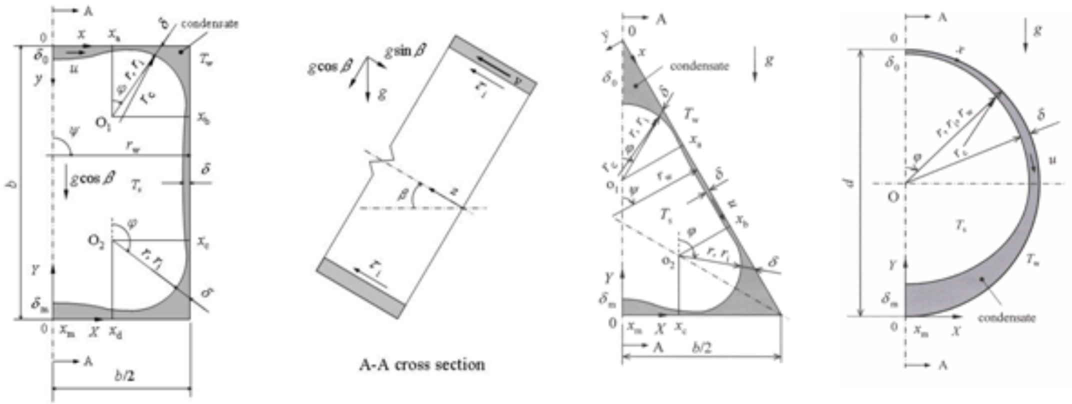
Research in Sustainable Thermal System Lab

Two-phase flow heat transfer and enhancement

- Condensation heat transfer in tubes and microchannels
- Condensation heat transfer on low-finned tubes
- Marangoni condensation heat transfer
- Flow boiling heat transfer in tubes and microchannels
- Flow boiling and condensation heat transfer of zerotropic mixtures
- Modelling and simulation of condensers and evaporators

Measurement of condensation in microchannels

Physical model and coordinates



Governing equation for condensate film – channel sides

$$\frac{(\rho_l-\rho_v)g\cos\beta}{3\nu_l}\frac{\partial}{\partial x}(\delta^3\sin\psi)+\frac{\sigma}{3\nu_l}\frac{\partial}{\partial x}\left\{\delta^3\frac{\partial}{\partial x}\left(\frac{1}{r_c}\right)\right\}+\frac{1}{2\nu_l}\frac{\partial(\tau_i\delta^2)}{\partial z}$$

gravity — surface tension — vapour shear stress

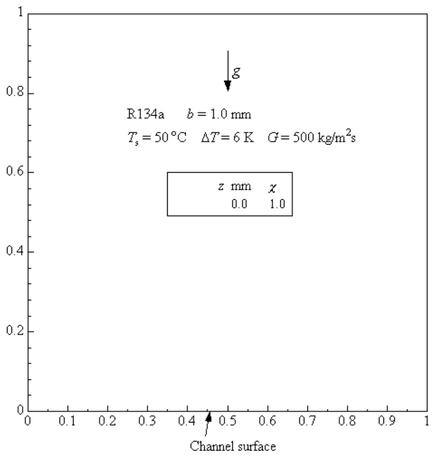
$$-\frac{(\rho_l-\rho_v)g\sin\beta}{3\nu_l}\frac{\partial}{\partial z}(\delta^3)-\frac{1}{3\nu_l}\frac{\partial}{\partial z}\left(\delta^3\frac{dP_l}{dz}\right)=\frac{1}{(1+\zeta\lambda_l/\delta)}\frac{\lambda_l(T_s-T_w)}{h_{fg}\delta}$$

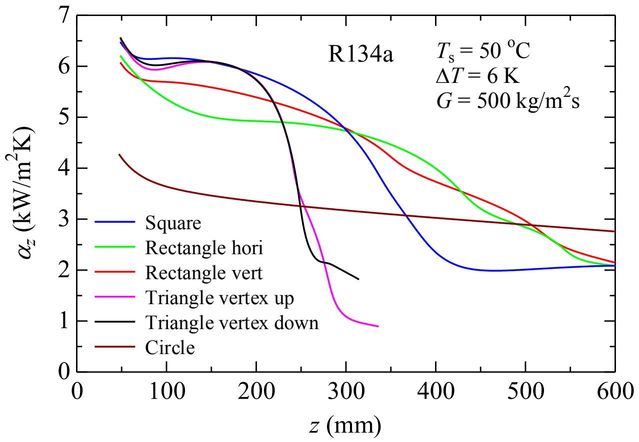
streamwise pressure gradient — condensation rate

$$\frac{1}{r_c}=\frac{\partial^2\delta/\partial x^2}{\{1+(\partial\delta/\partial x)^2\}^{3/2}}$$

Interface resistance term (generally negligible)

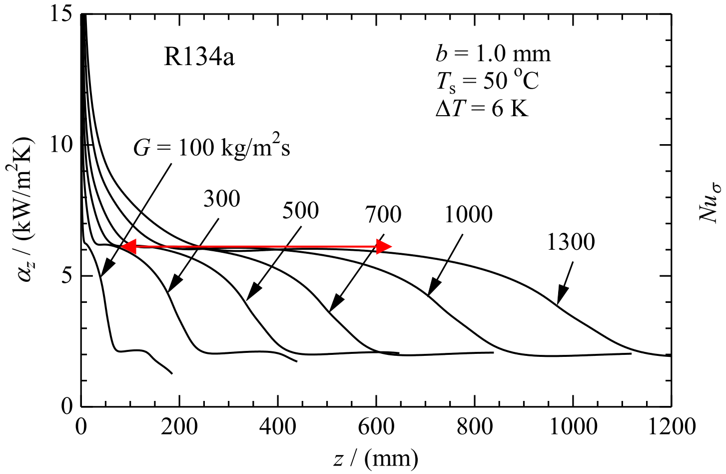
curvature of condensate surface

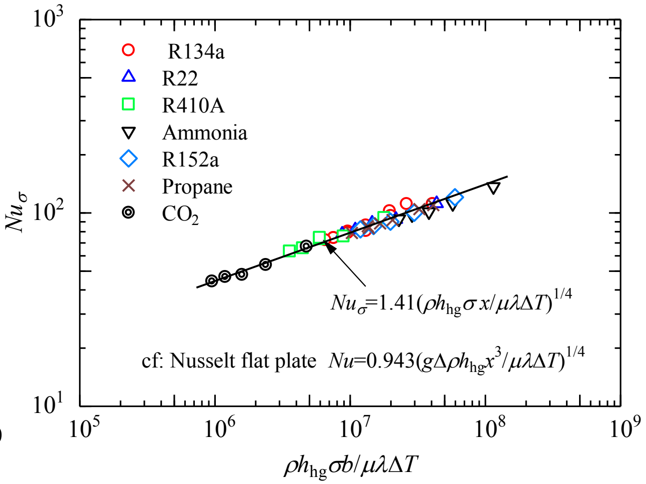




ASME J. Heat Transfer 2005, **127**, 1207-1213

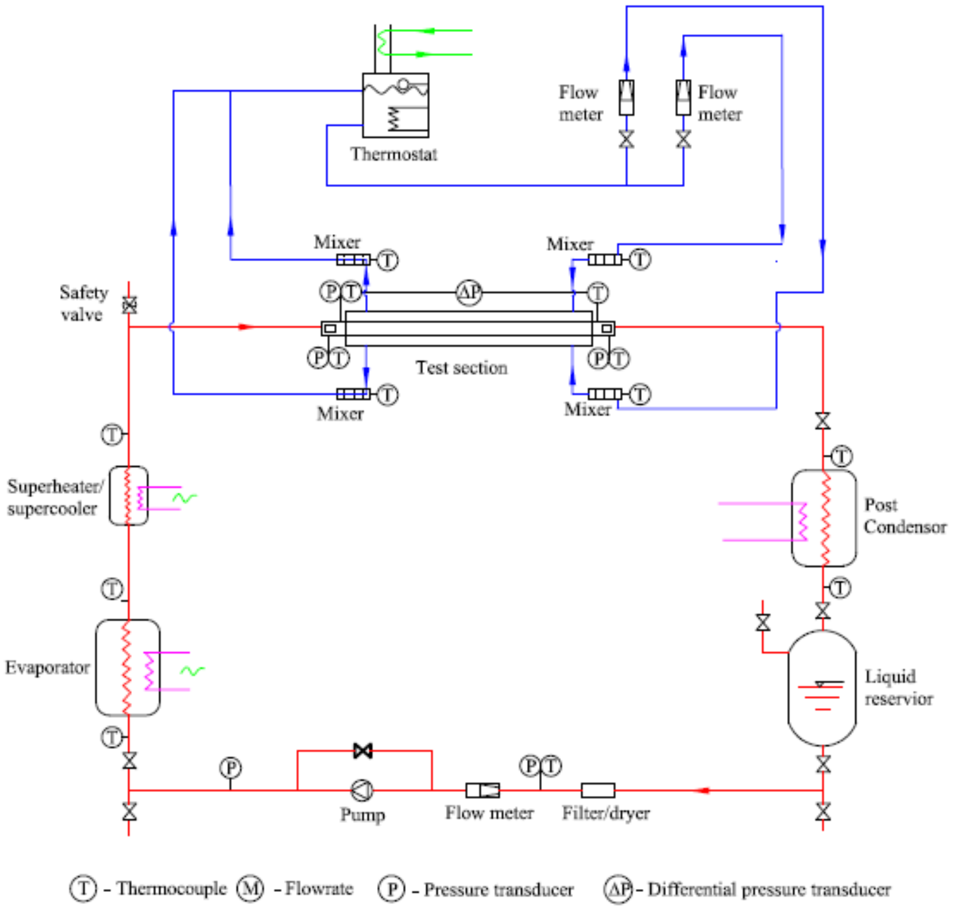
Surface tension dominated regime

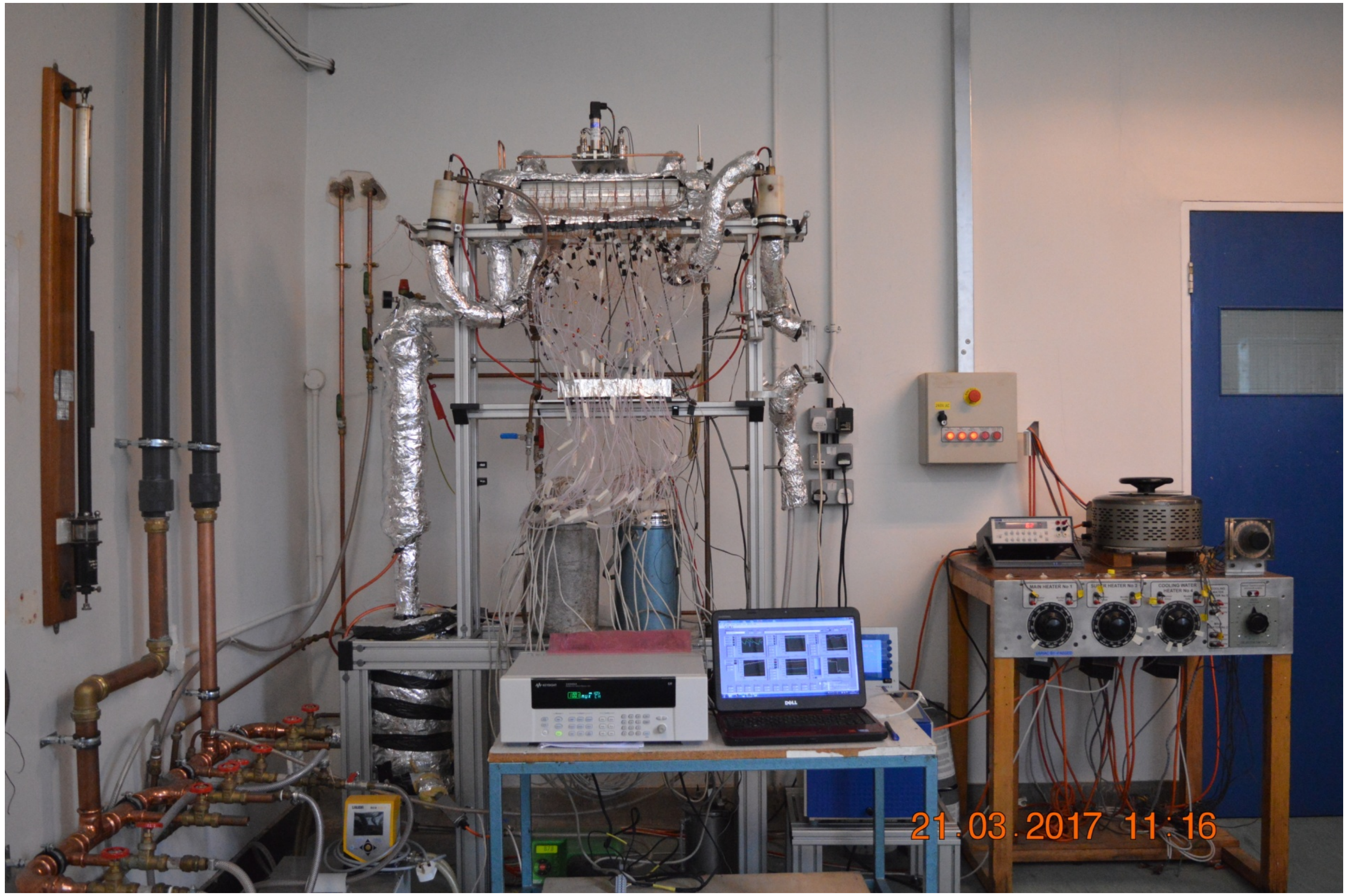




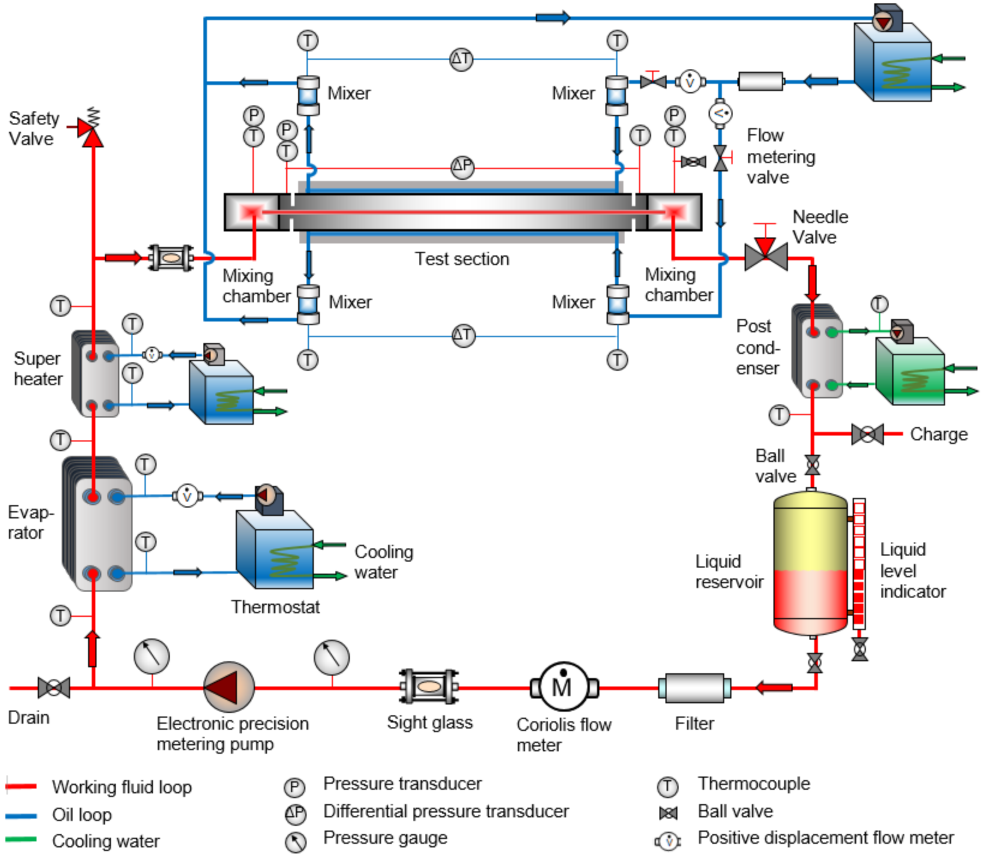
Int. J. Heat Mass Transfer 2011, **54**, 2525-2534

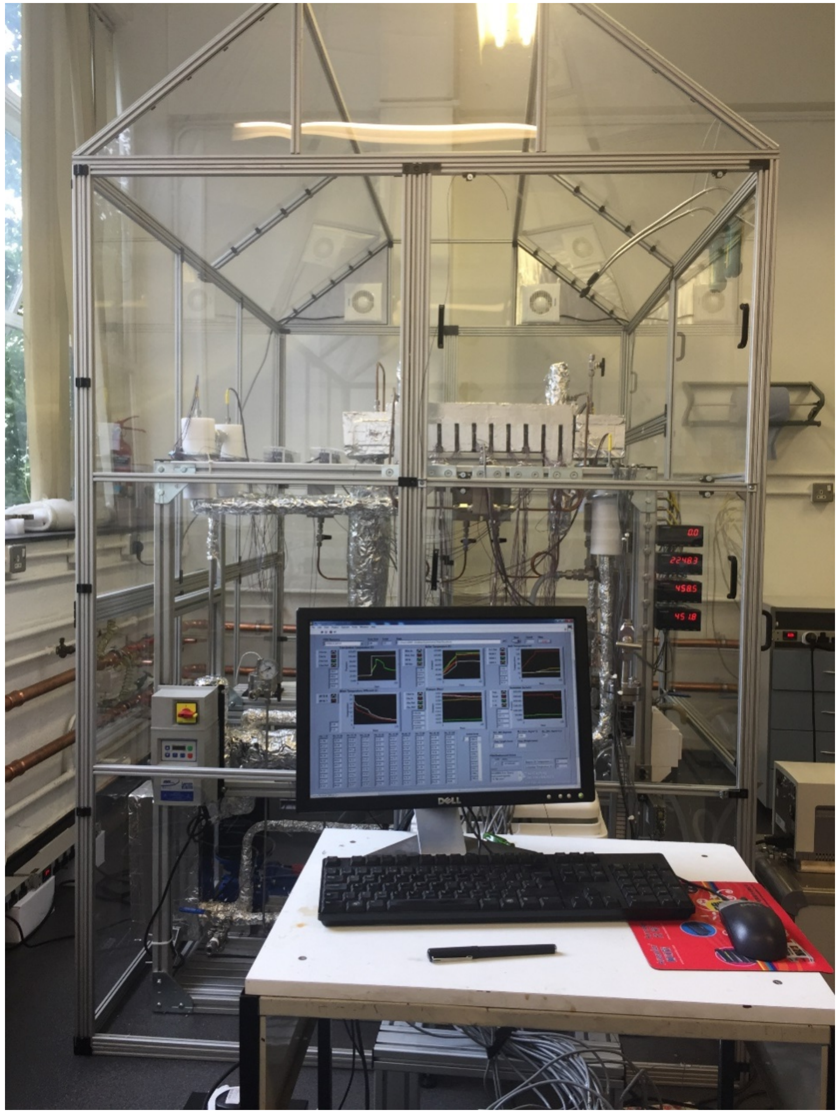
Measurement of condensation in microchannels

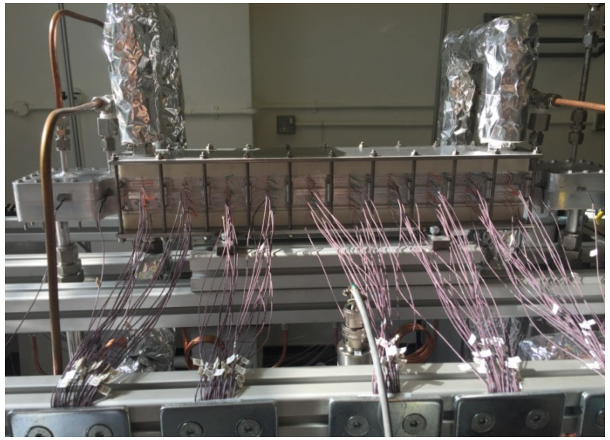


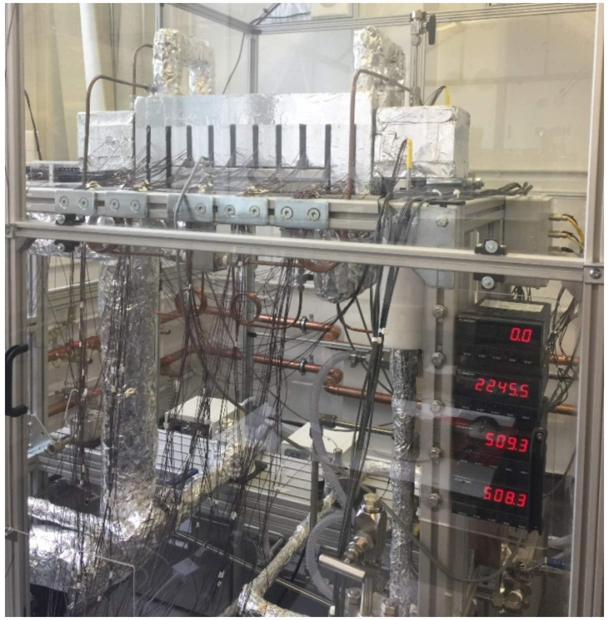


Measurement of condensation in microchannels









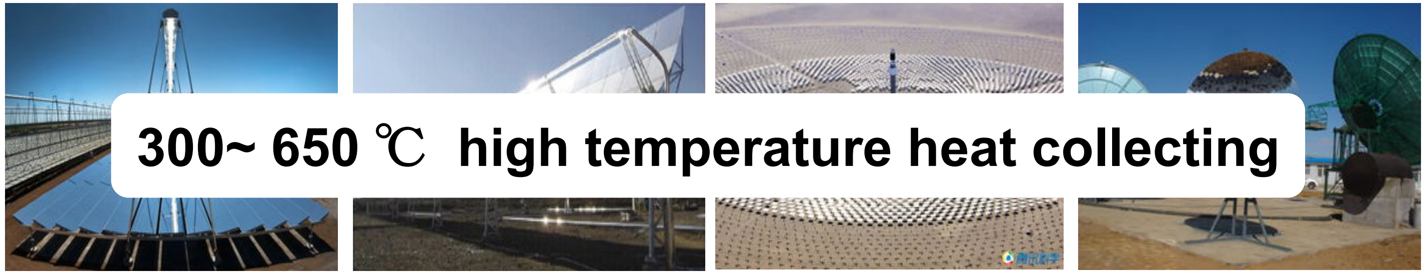
Solar Collector Integrated with a Pulsating Heat Pipe and a Compound Parabolic Concentrator

Rongji Xu et al., Experimental investigation of solar collector integrated with a pulsating heat pipe and a compound parabolic concentrator, ***Energy Conversion and Management***, 148 (2017) 68-77.

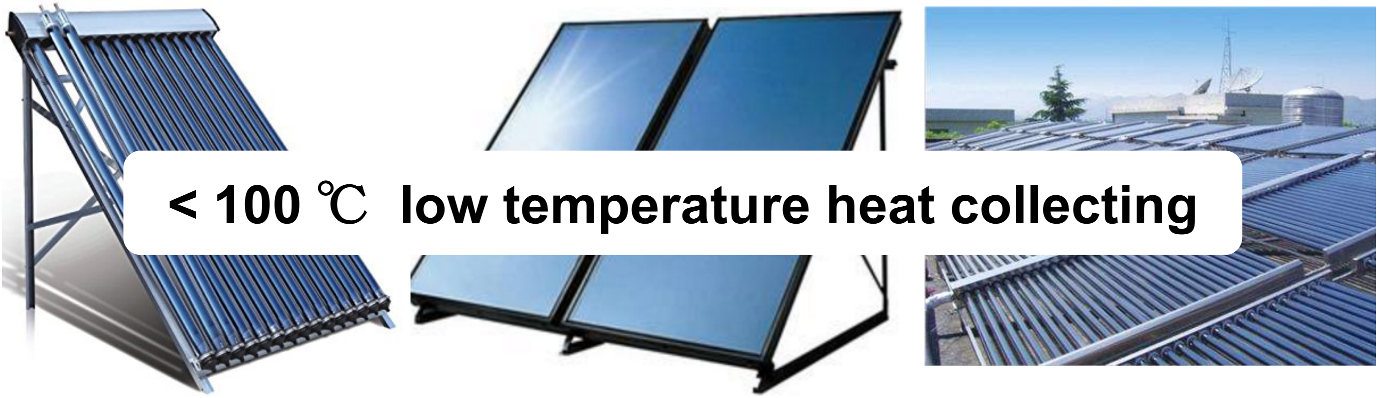
Rongji Xu et al., Numerical and experimental investigation of a compound parabolic concentrator-capillary tube solar collector, ***Energy Conversion and Management***, 204 (2020) 112218.

Various temperature heat collecting

Fresnel lens | Solar parabolic through | Solar power tower | Dish solar



- km Scale
- High concentration
- Tracking device
- West China



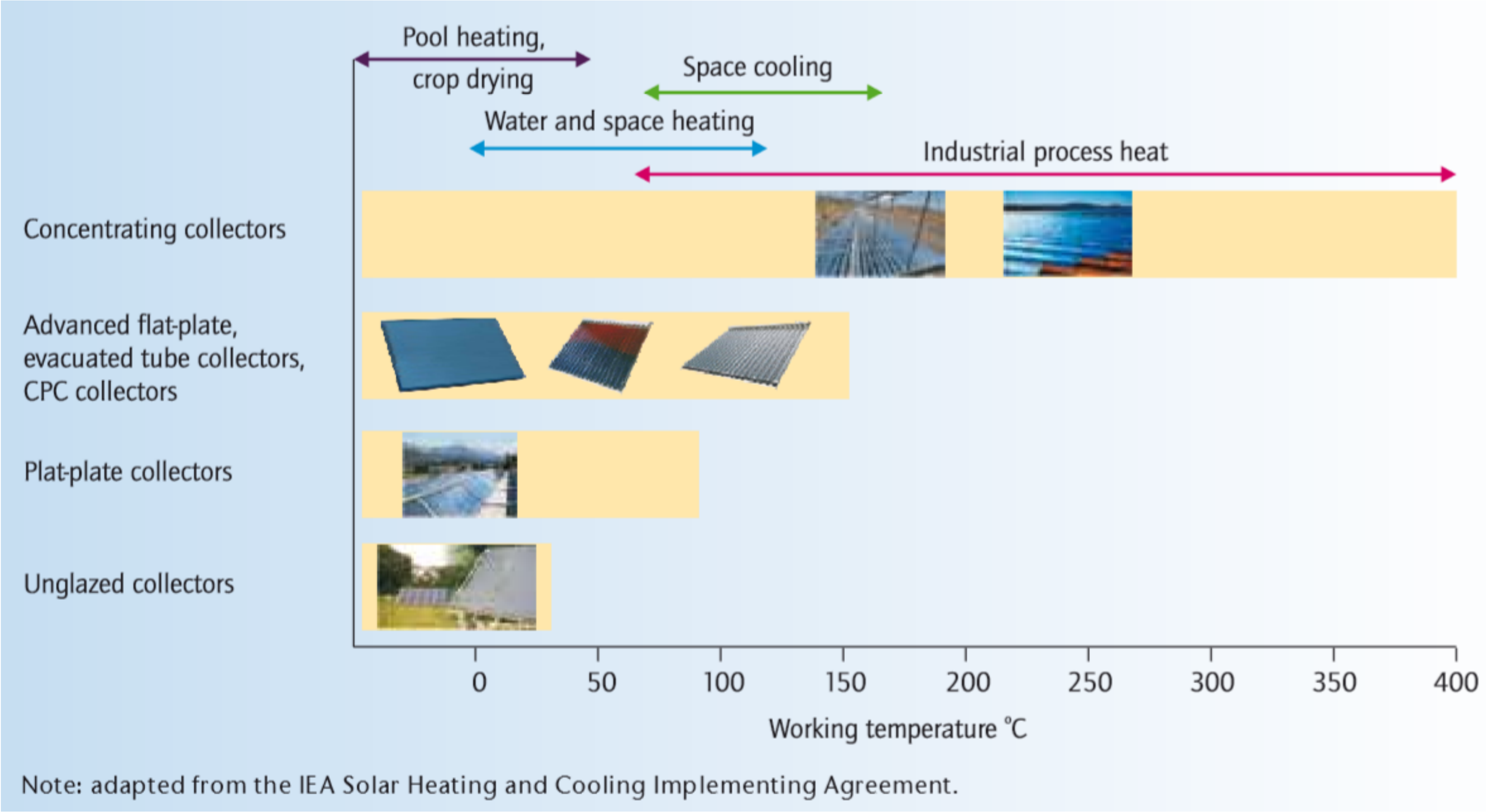
Solar evacuated tube | Flat plate | Heat collector array

- m Scale
- No concentration
- No tracking
- Building integrated

Demand：70-200℃

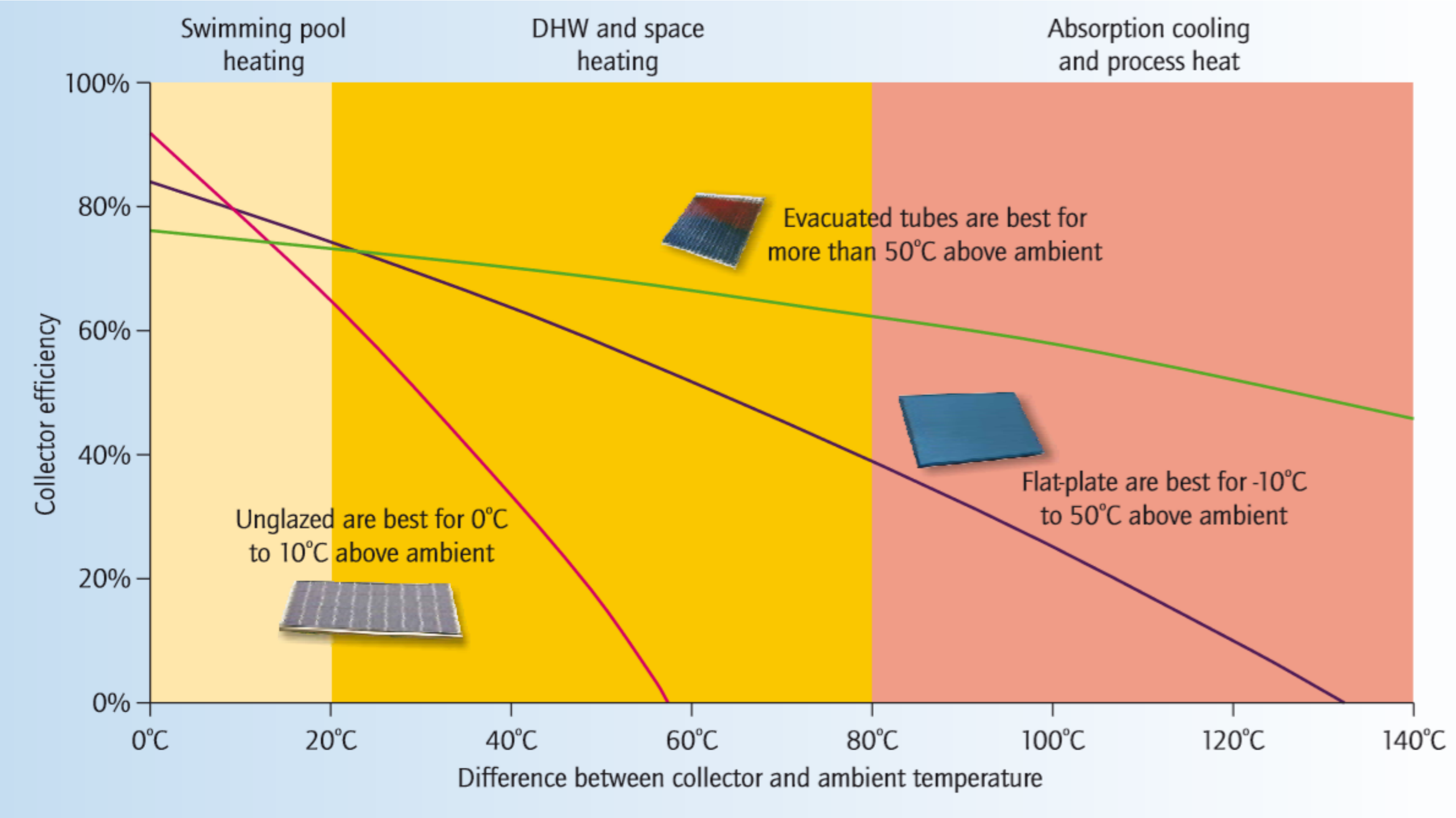
m scale + concentrating + no tracking + building intergrated

Working temperature for different solar collectors



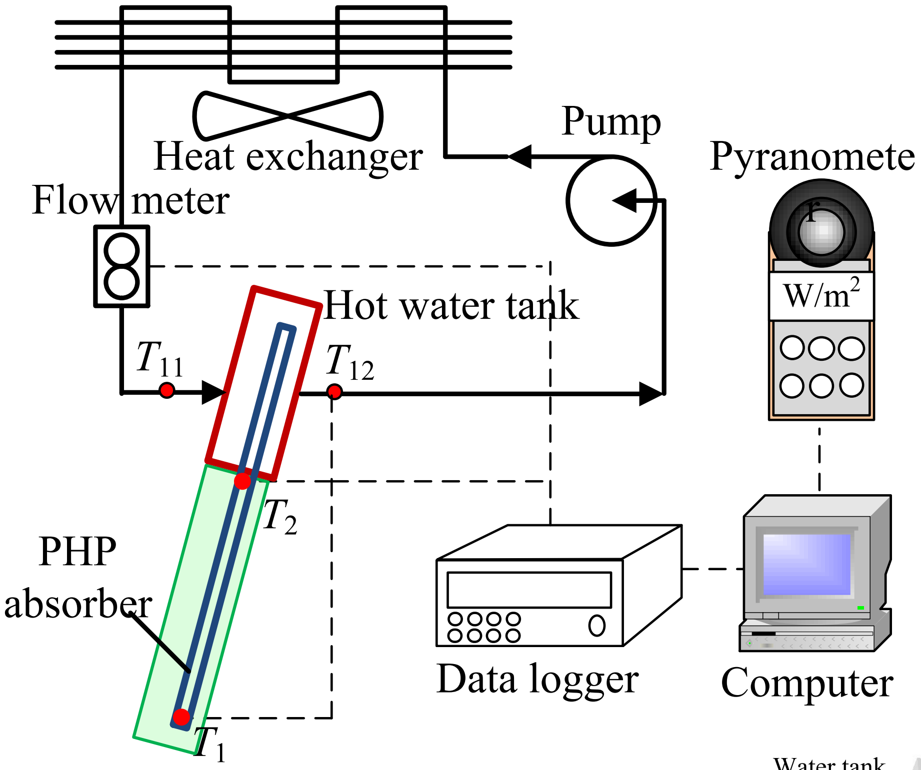
https://webstore.iea.org/technology-roadmap-solar-heating-and-cooling

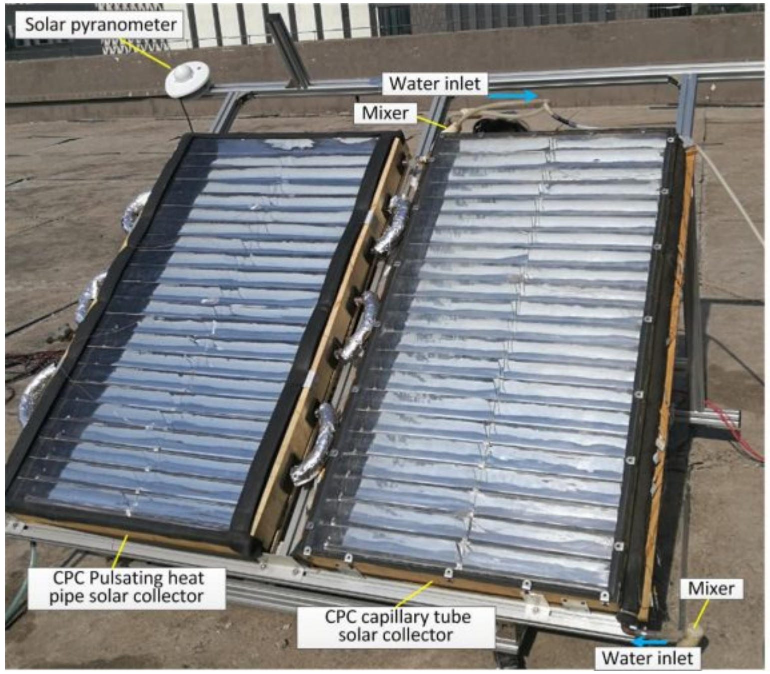
Comparison of solar collector efficiency

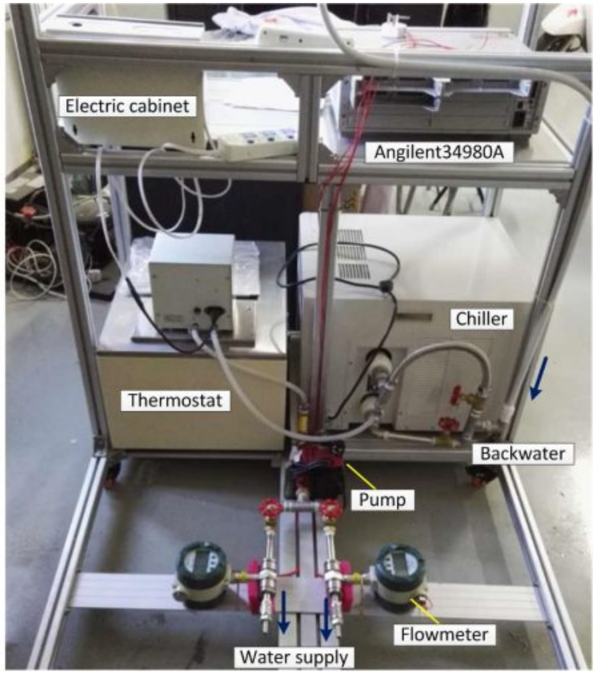


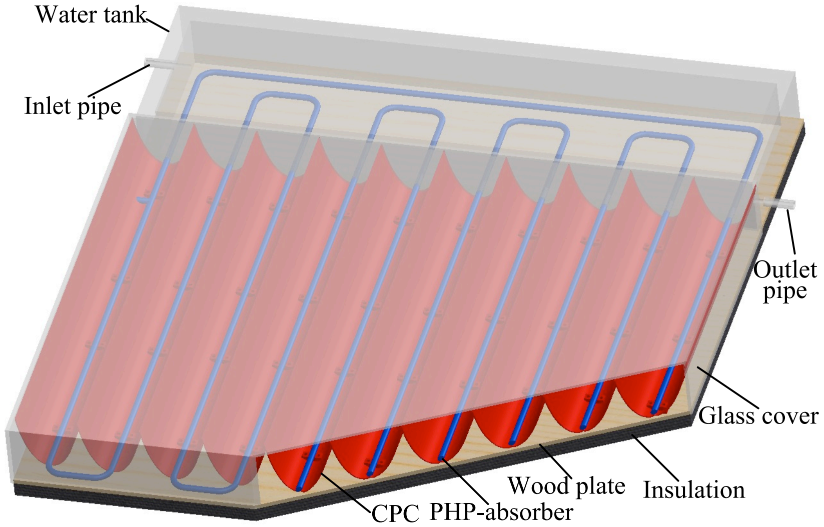
https://webstore.iea.org/technology-roadmap-solar-heating-and-cooling

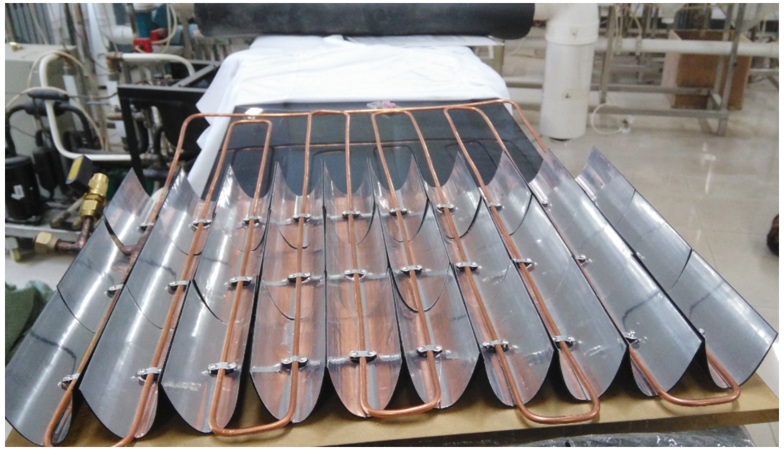
Solar collector prototype



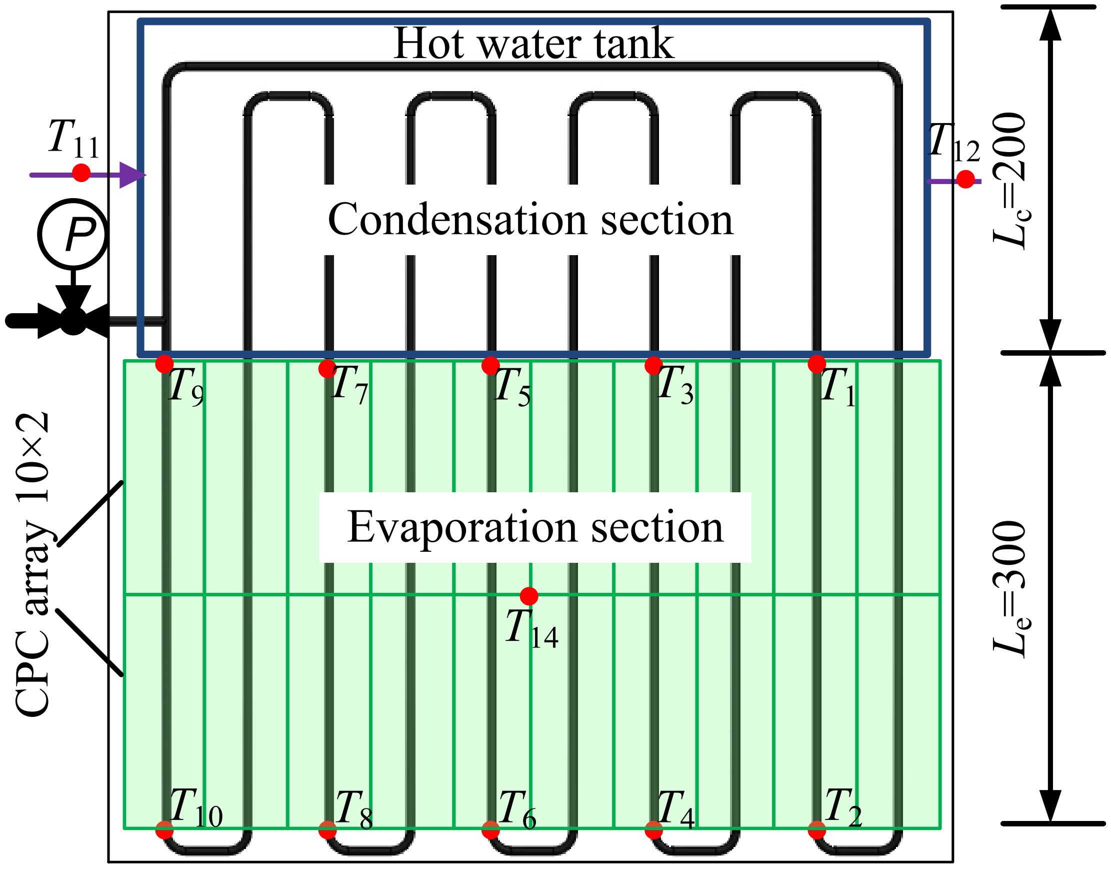








Dimensions and temperature measurements

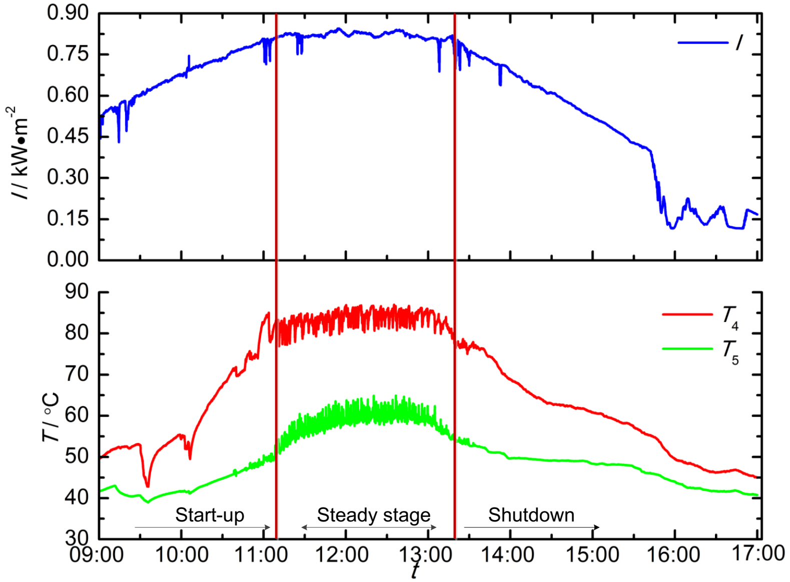


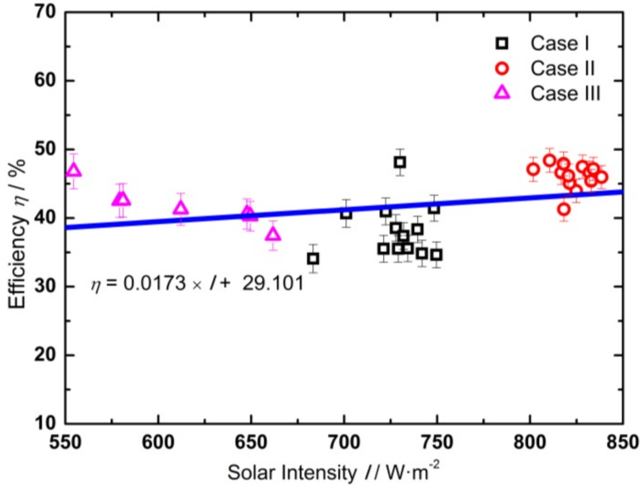
$$R_T = (T_e - T_c)/(IA)$$

$$Q_w = c_w m_w (T_{out} - T_{in})$$

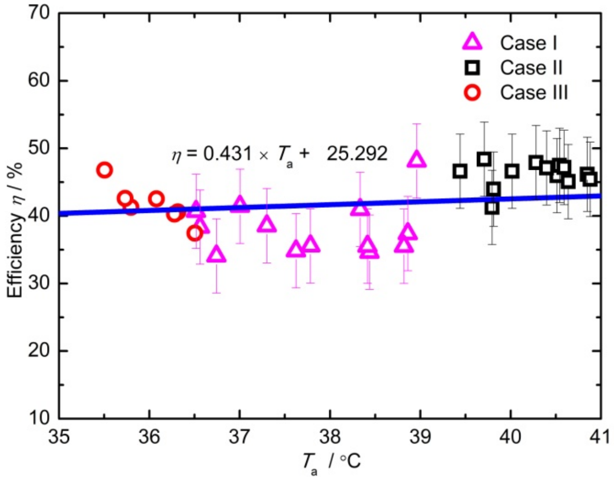
$$\eta = \frac{c_w m_w (T_{out} - T_{in})}{IA}$$

Characteristics of the PHP absorber

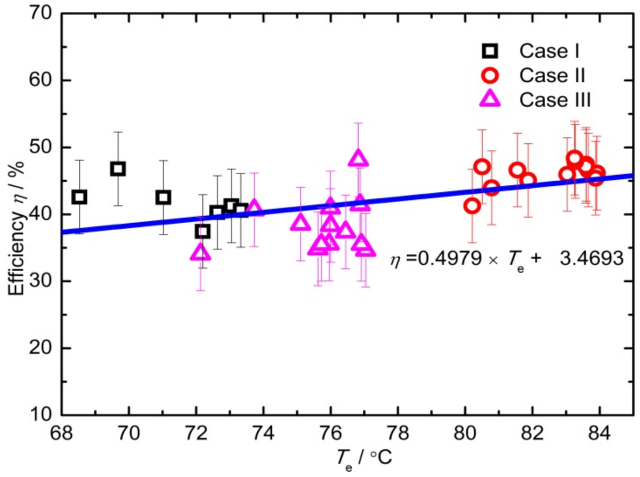




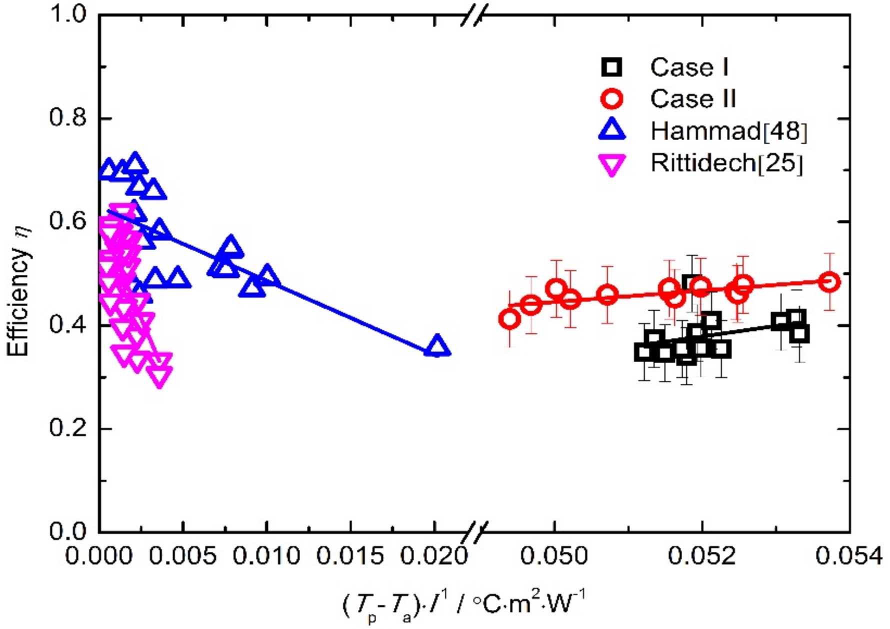
Solar irradiation intensity



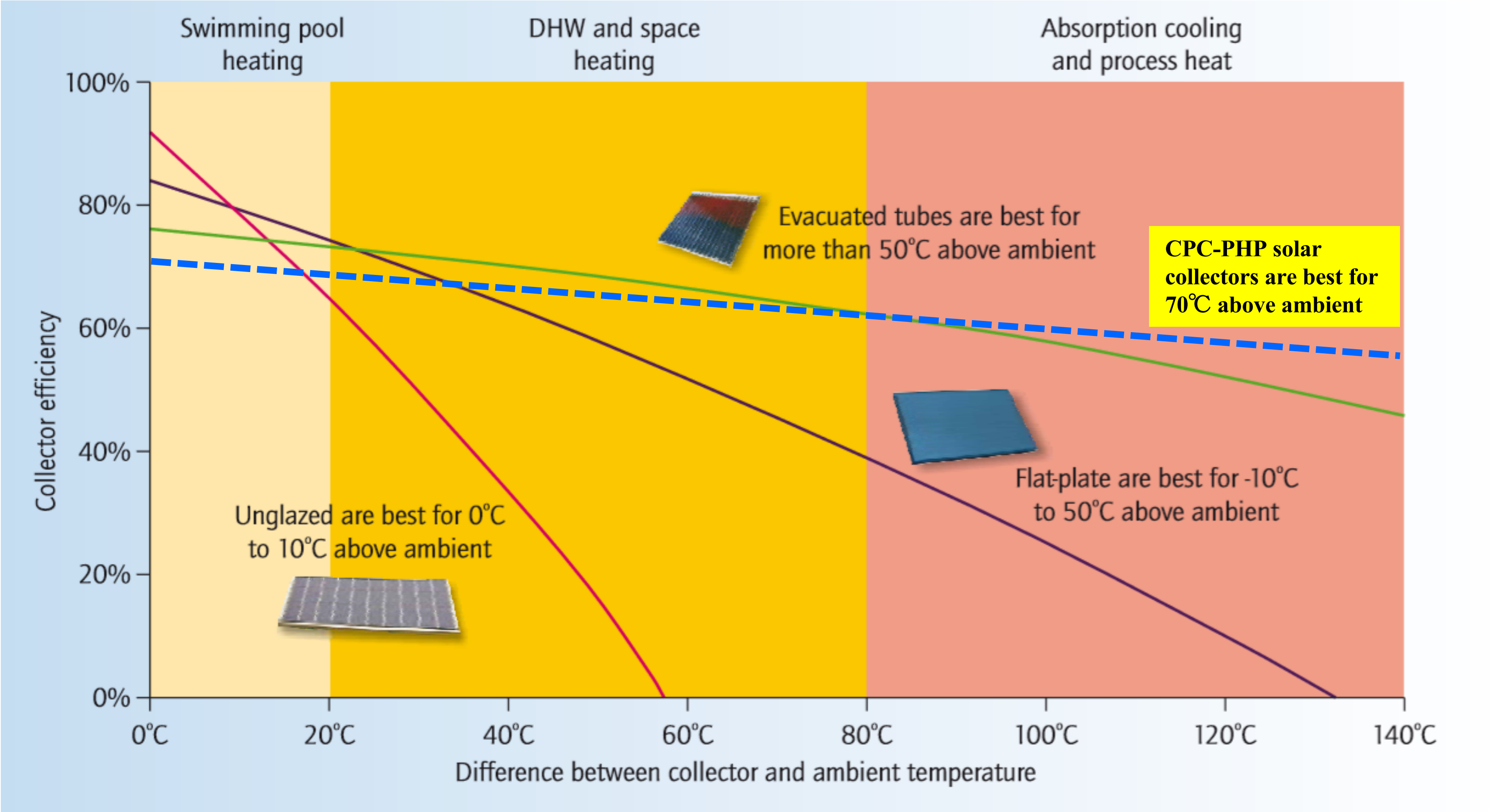
Ambient temp.



Evaporation temp.



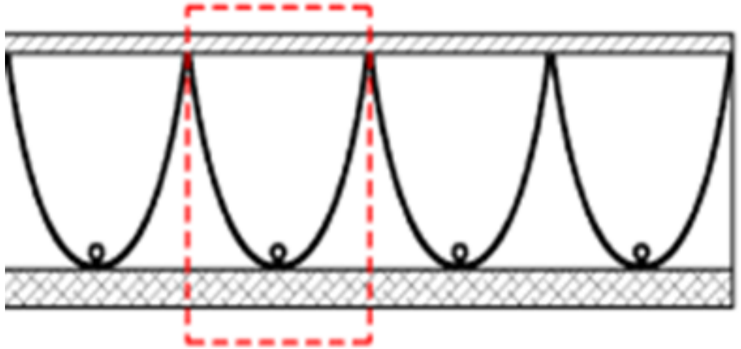
Comparison of solar collector efficiency

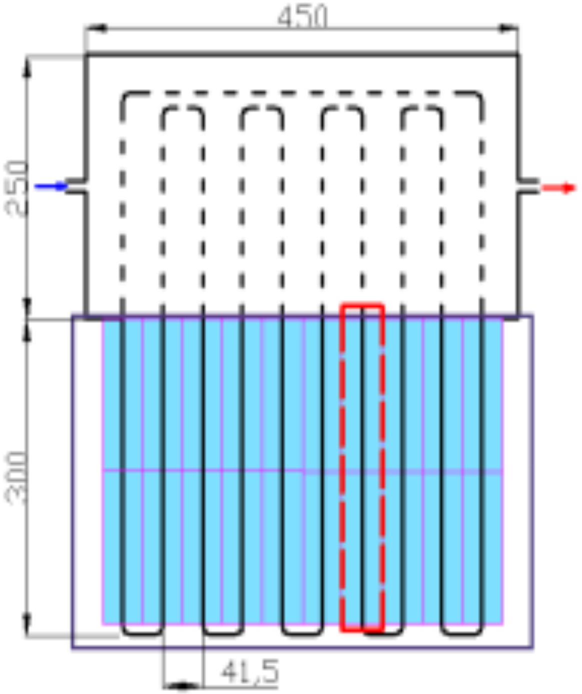


https://webstore.iea.org/technology-roadmap-solar-heating-and-cooling

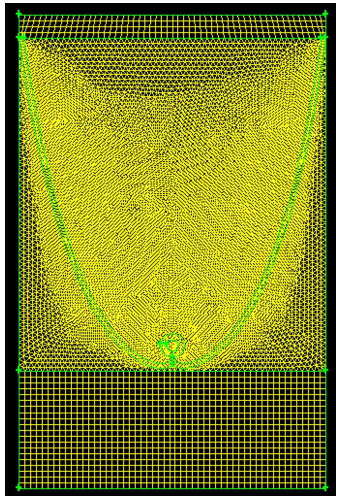
Numerical simulation of the solar collector

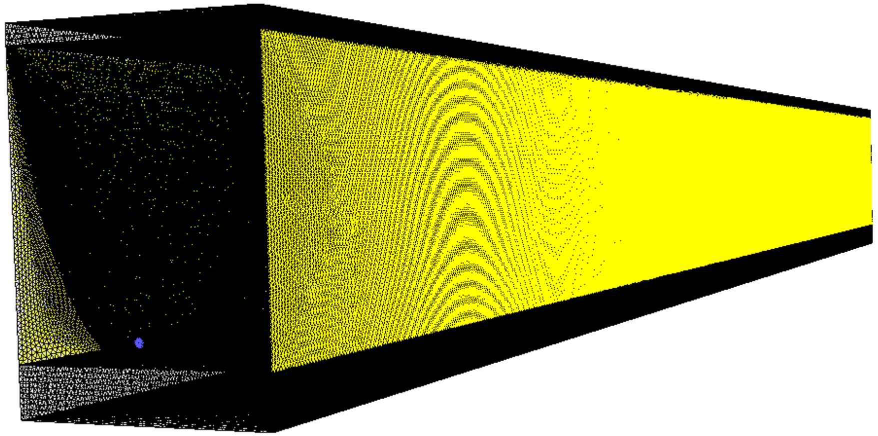
- **Model**



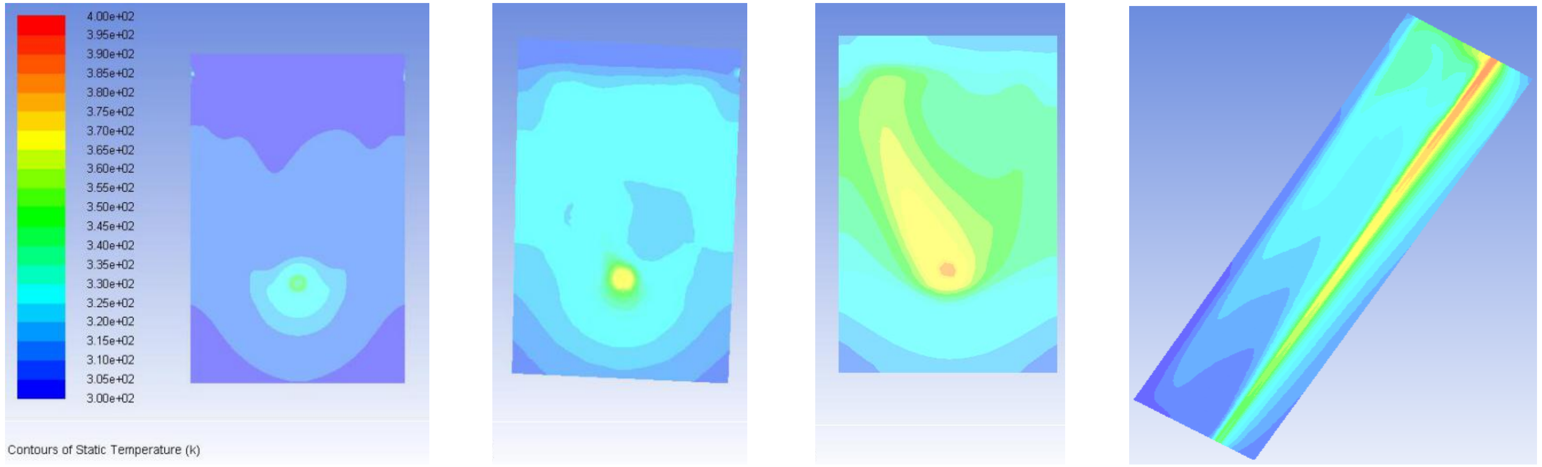


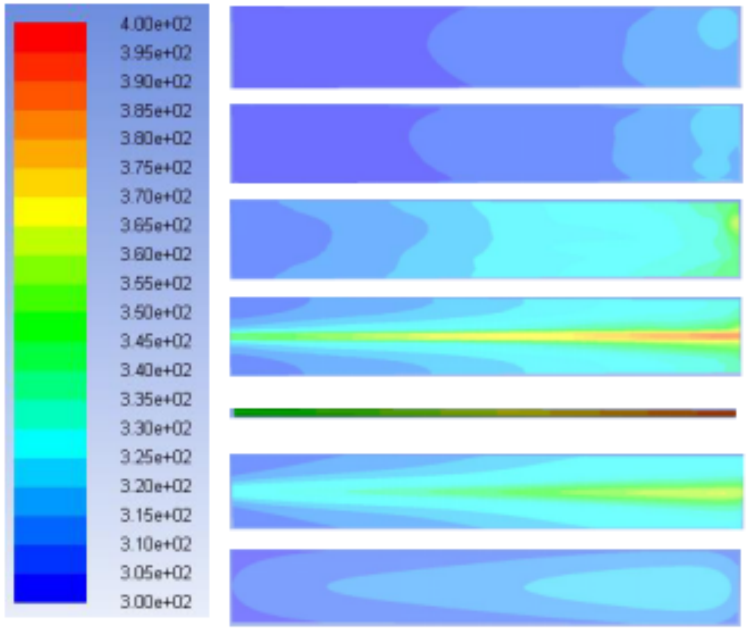
- **Mesh**

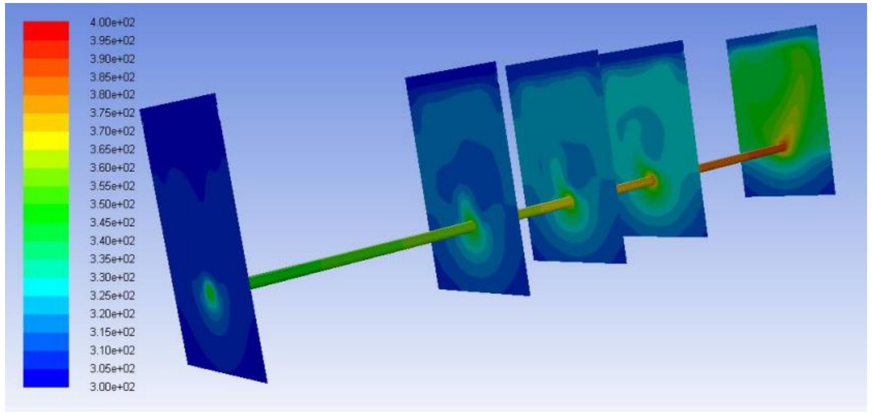


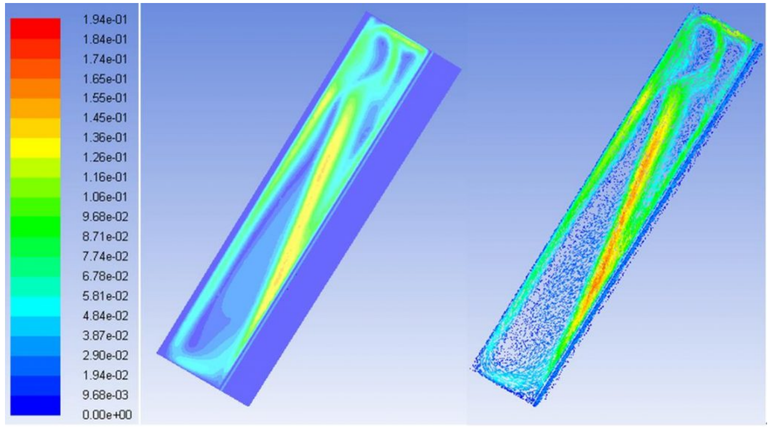


Temperature distribution









Outside surface of glass

Inside surface of glass

Air gap

Cross section of heat collection tube

Surface of heat collection tube

Inside surface of bottom plate

Outside surface of bottom plate

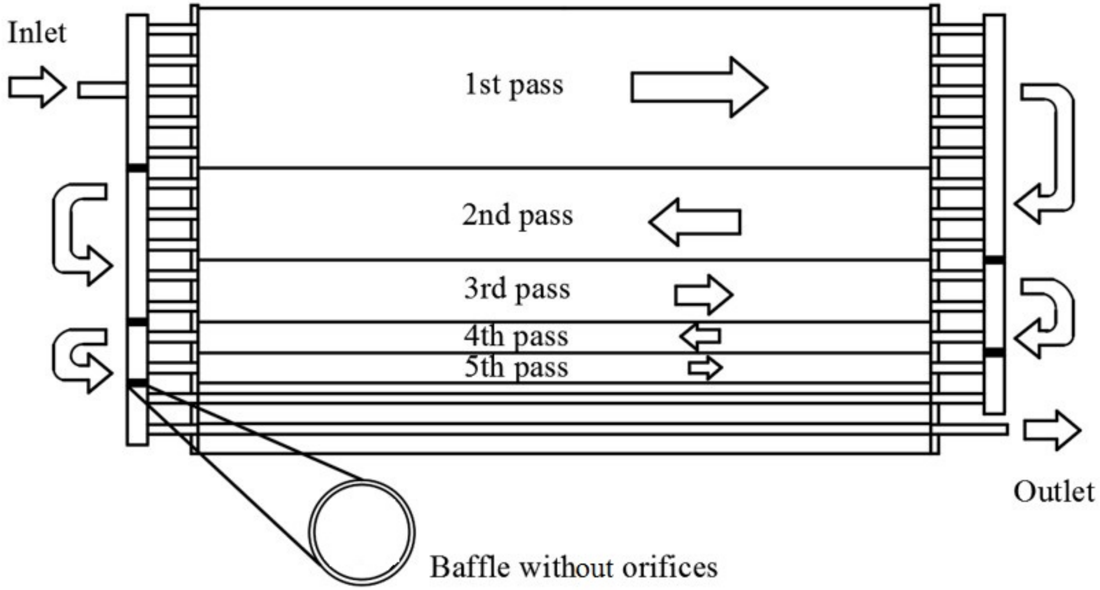
Numerical Simulation of Multi-pass Parallel Flow Condensers

Nan Hua et al., Numerical simulation of multi-pass parallel flow condensers with liquid-vapour separation, ***Int. J. of Heat and Mass Transfer***, 142(2019) 118469.

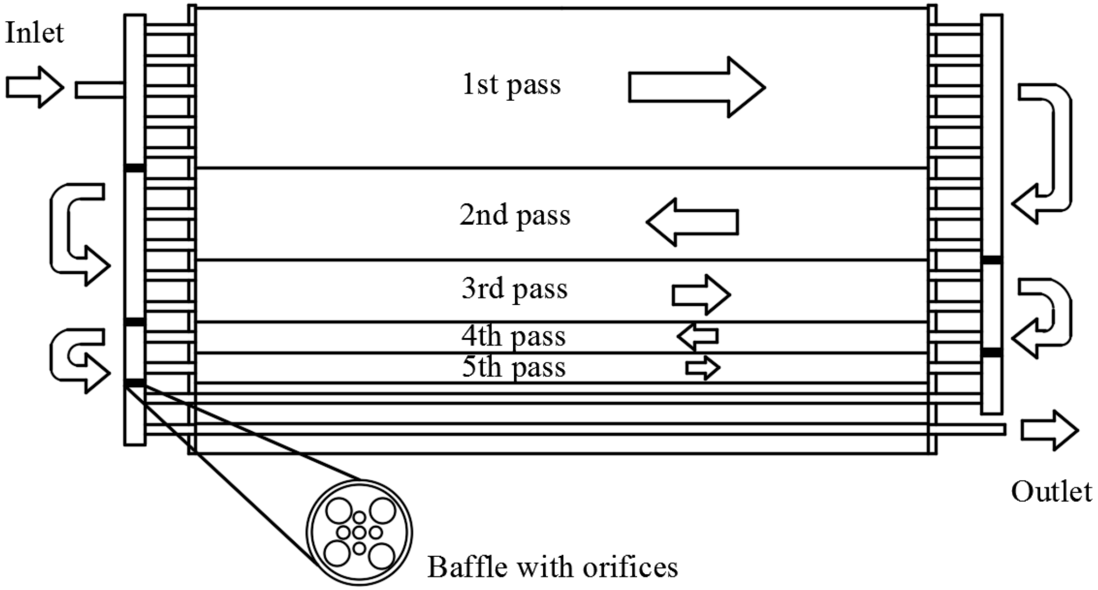
Nan Hua et al., Numerical simulation of thermal-hydraulic performance of a round tube-fin condenser with liquid-vapour separation, **16th UK Heat Transfer Conference**, Nottingham University, UK, 8-10 September 2019.

Multi-pass parallel-flow condensers (MPFC)

Condenser without L-V separation

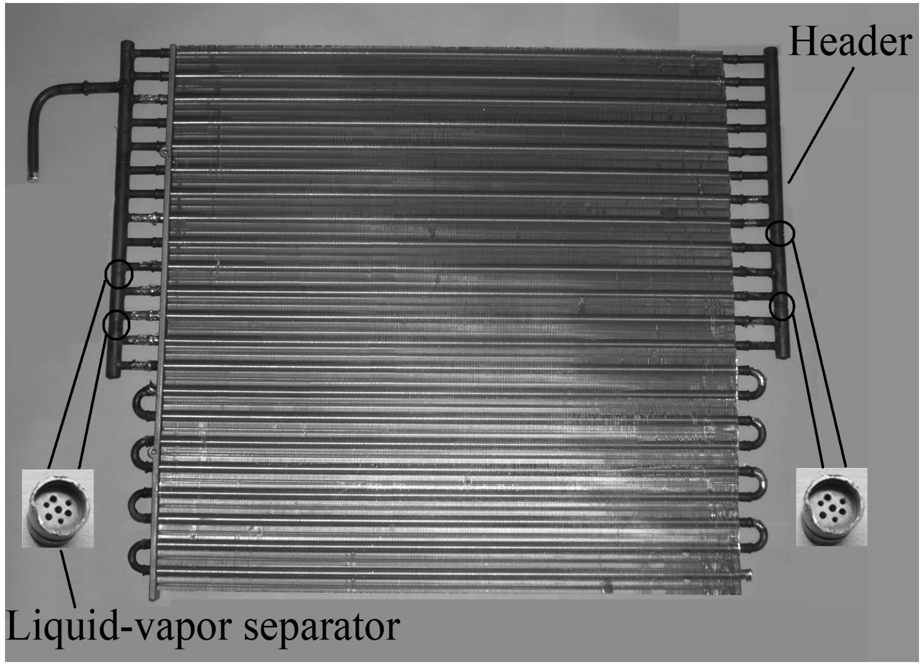


Condenser with L-V separation



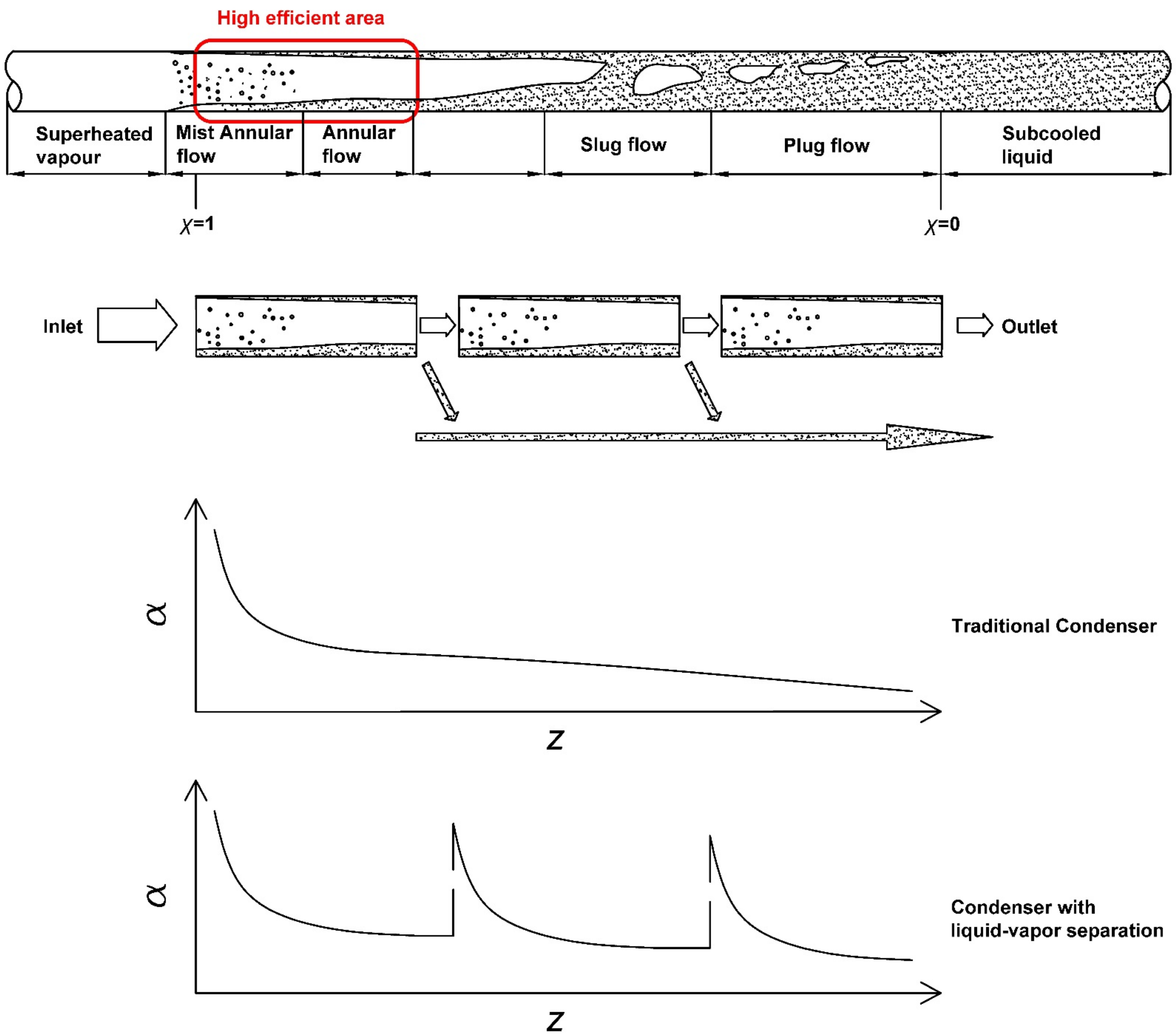
Condenser with L-V separation

Schematic of LSC



Condenser

Mechanism of Liquid-vapor separation



Details of test condenser

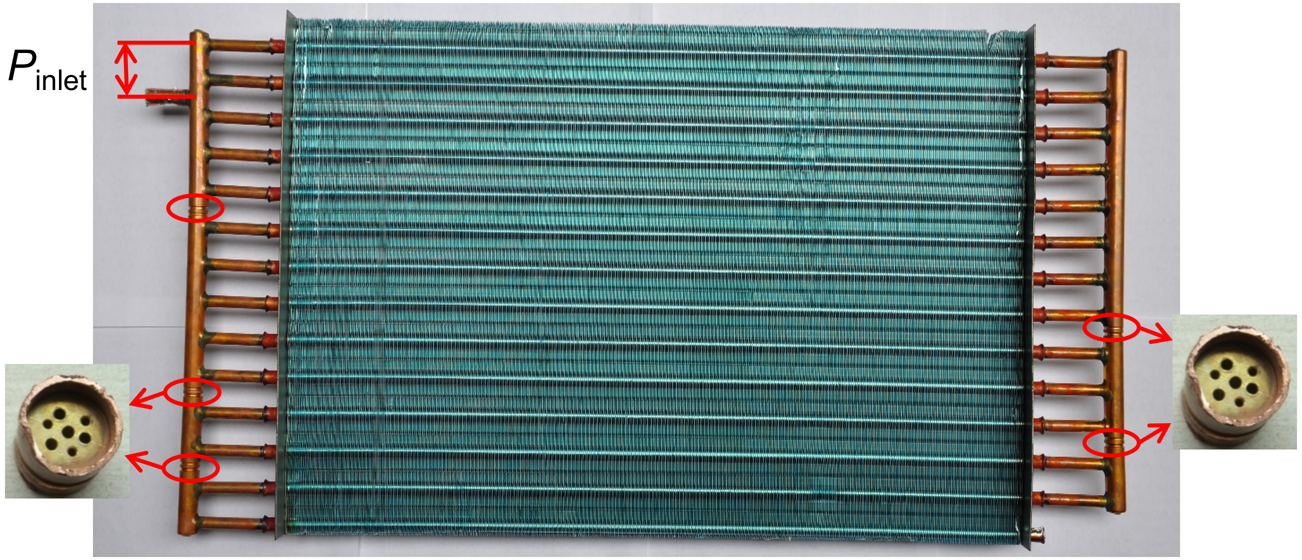


Figure Picture of the condenser

Table 2 Details of the condenser

Heat transfer tube type	Helical micro-fin tubes
Tube material	Copper
Tube length L_1 (mm)	490
Tube pitch P_t (mm)	21
Inlet pipe position P_{inlet} (mm)	31.5
Number of tube N_t	14
Tube-pass arrangement	5-3-2-1-1-1-1
Air side fin type	Slit-louvered fin
Fin material	Aluminium

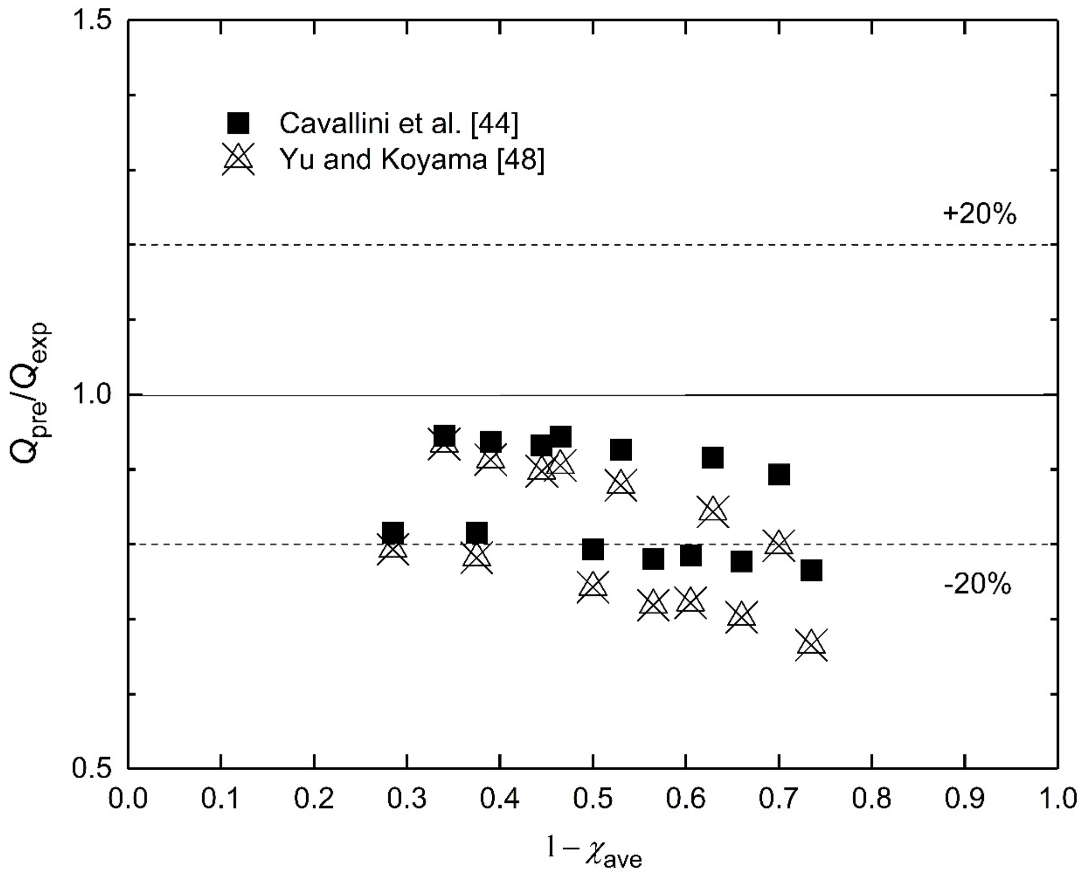
Table 3 Dimensions of Helical micro-fin tubes

D_o (mm)	d_i (mm)	p_t (mm)	h (mm)
7.35	6.89	0.41	0.15
t_b (mm)	γ (℃)	β (℃)	n_s
0.14	53	18	60

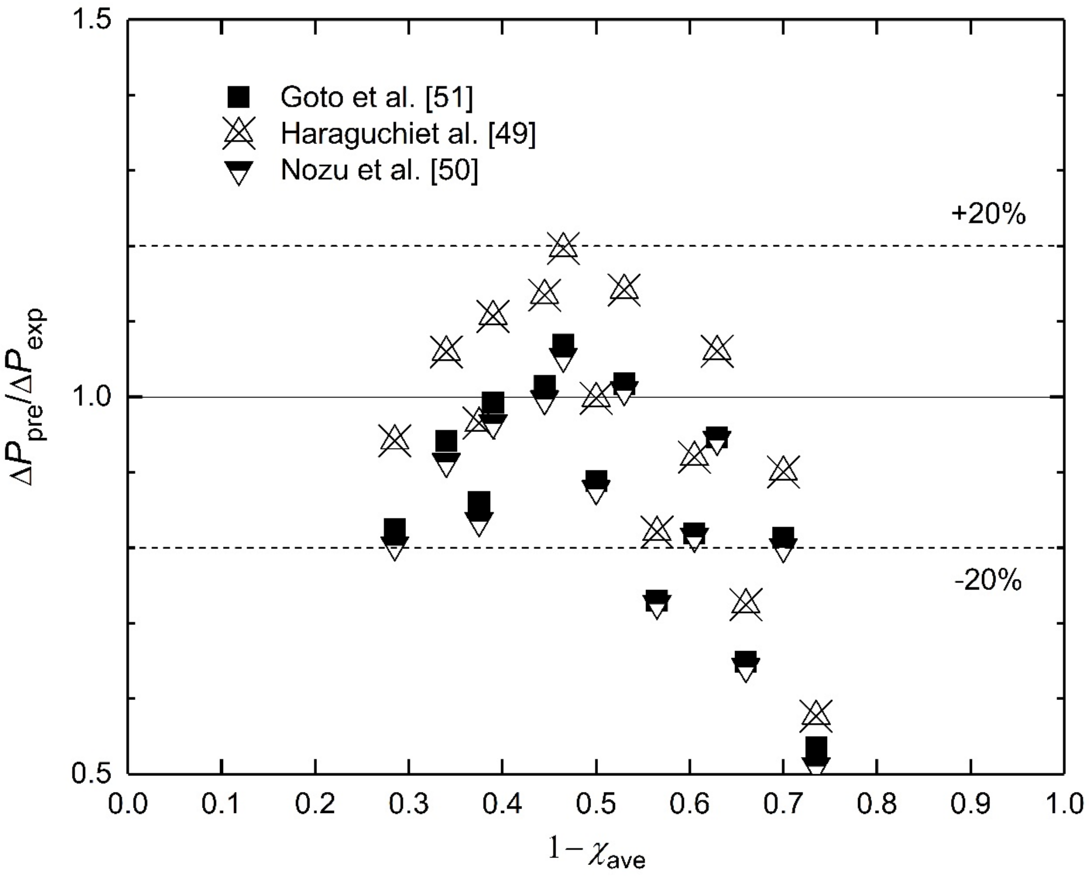
Table 4 Dimensions of the Slit-louvered fin

F_s (mm)	δ_f (mm)	S_h (mm)	S_s (mm)
1.35	0.115	1.0	1.2
P_l (mm)	S_n	N_r	N_f
12.7	6	1	365

Simulation results *vs* experimental data



Heat transfer rate



Pressure drop

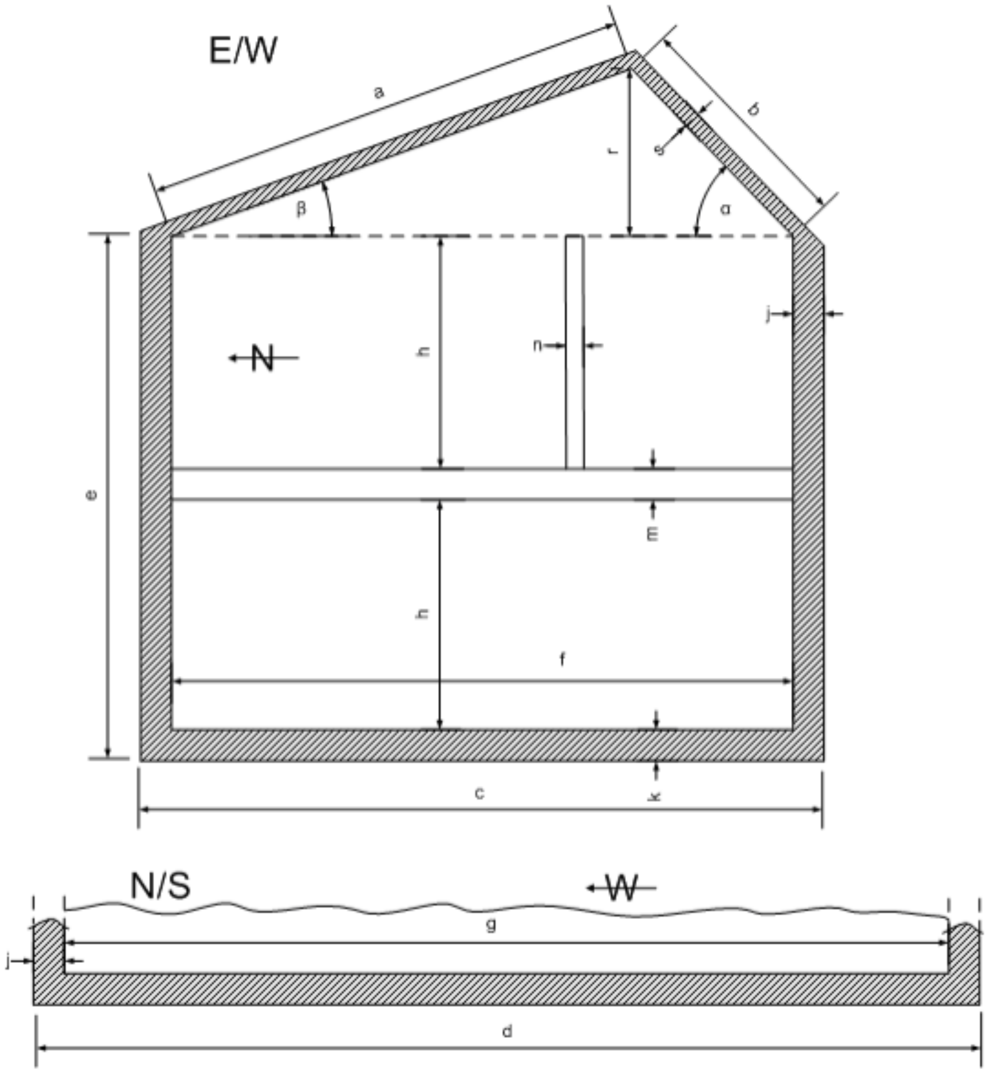
The predictions of the model agree with the experimental data within ±20%.

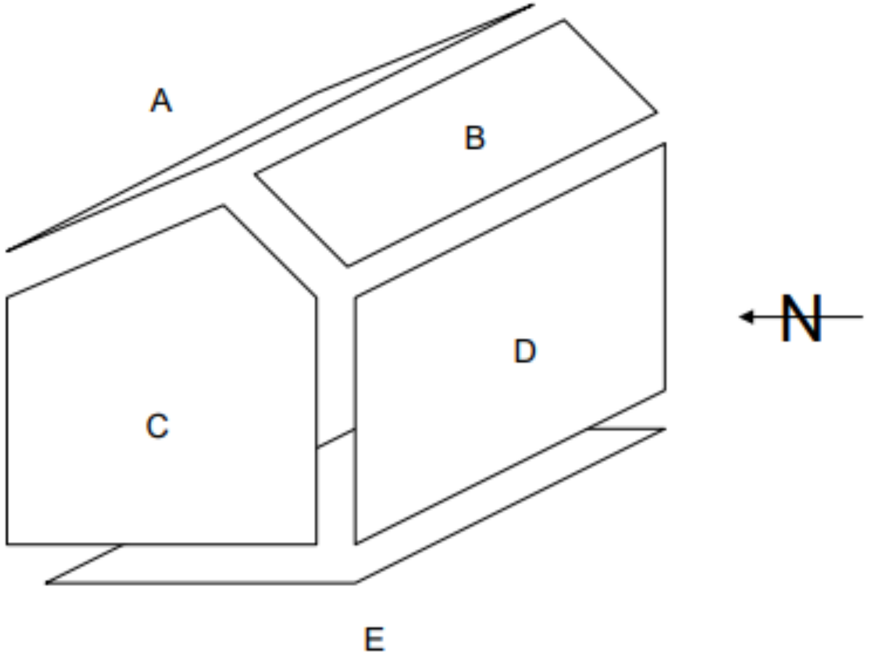
Solar assisted air source heat pumps (SAASHPs) for domestic space heating and hot water

Liwei Yang et al., Review of the advances in solar-assisted air source heat pumps for the domestic sector, ***Energy Conversion and Management***, 247(2021) 114710.

Liwei Yang et al., Analysis of operation performance of three indirect expansion solar assisted air source heat pumps for domestic heating, ***Energy Conversion and Management***, 252(2022) 115061.

IEA Standard Reference Building (SFH 45)



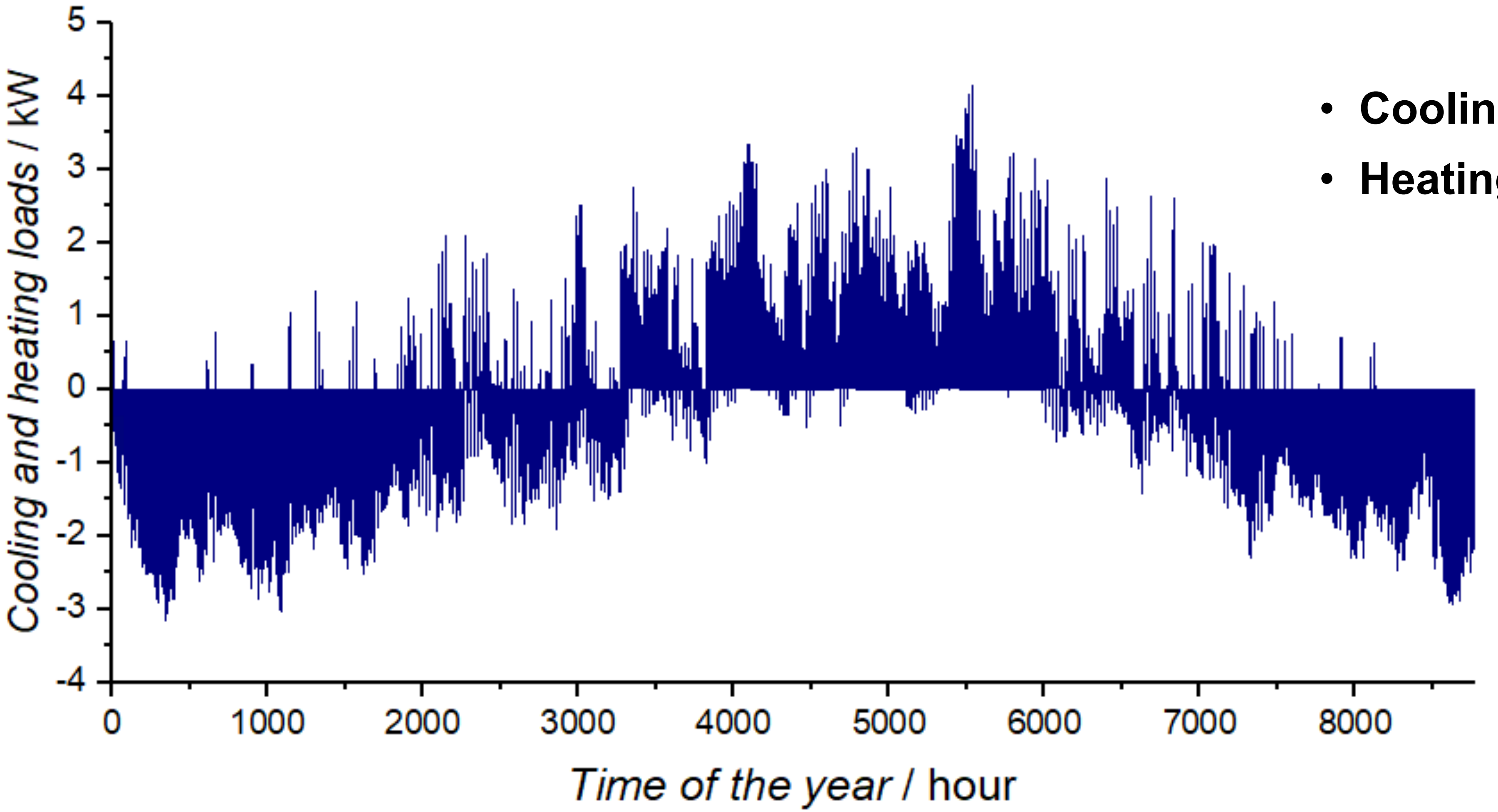


Total floor area: 140 m²

Relevant parameters:

- **building geometry**
- **envelop material and thickness**
- **windows material and area**
- **heat gains from equipment & occupants**
- **ventilation**

Heating Load and Cooling Load



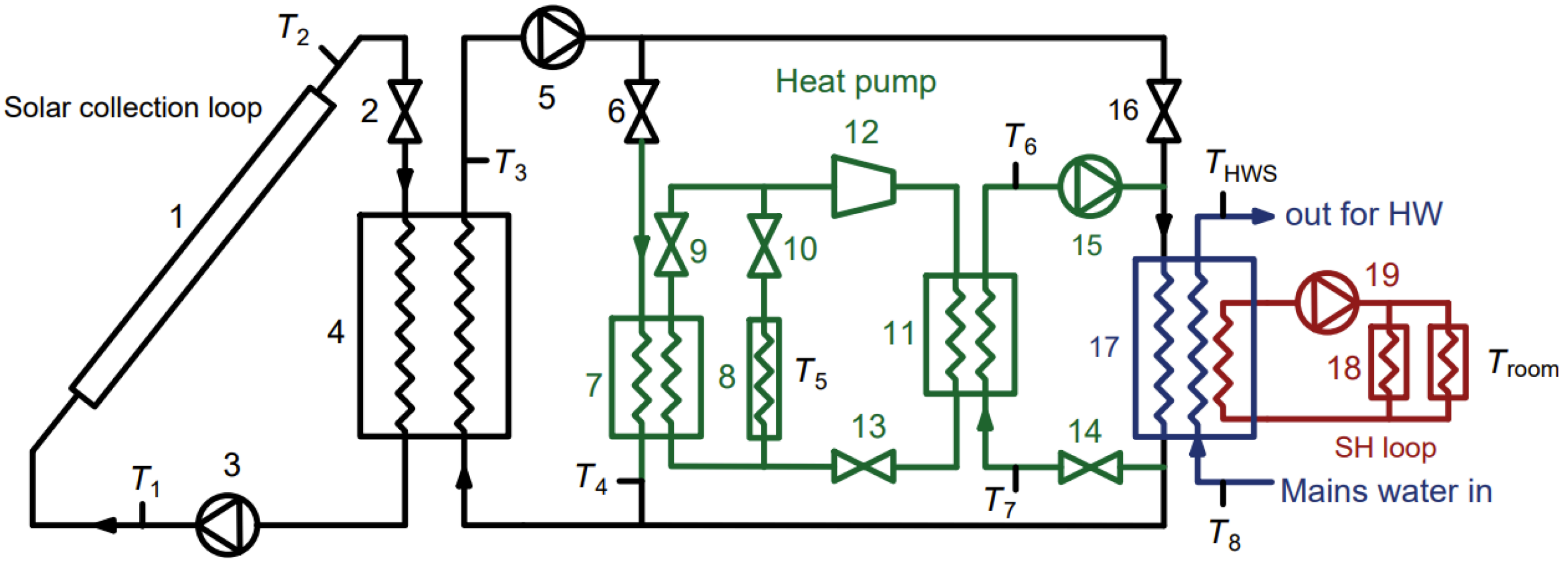
- **Cooling load (+)**
- **Heating load (-)**

Calculation conditions:

- **Set T_{air} = 18 °C**
- **Weather: Reference Year London**

- **Peak heating load: 3.15 kW**
- **Averaged heating load: 1.24 kW**

IX-SAASHPs

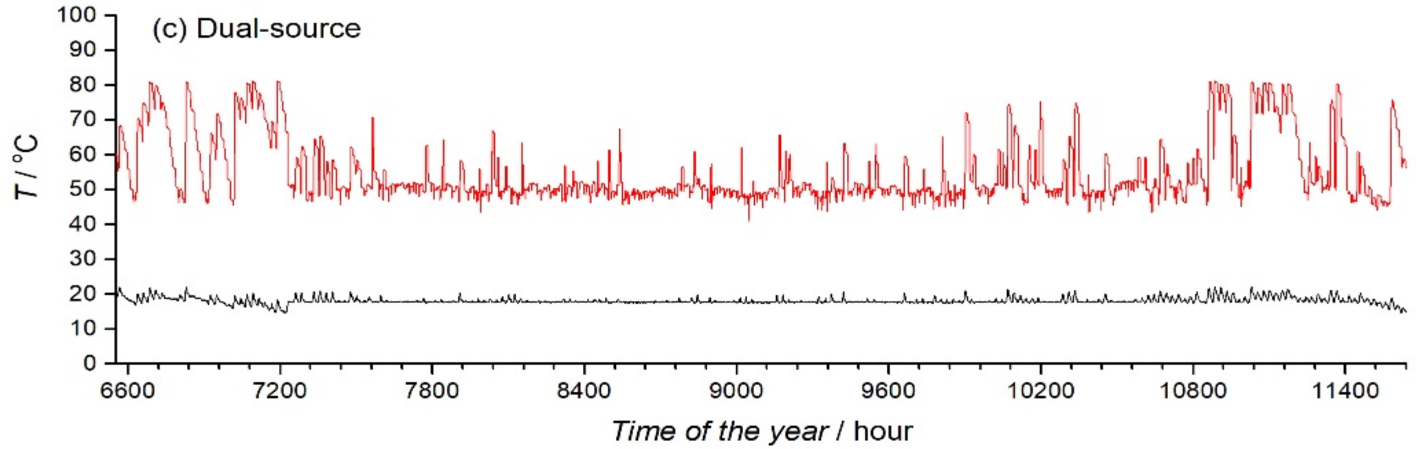


1: Solar collector 2, 6, 9, 10, 14, 16: Valves 3: Pump 1 4: TES tank 1 5: Pump 2
7: Water-to-refrigerant evaporator 8: Air-to-refrigerant evaporator
11: Condenser 12: Compressor 13: Expansion valve 15: Pump 3
17: TES tank 2 18: Radiant floor 19: Pump 4

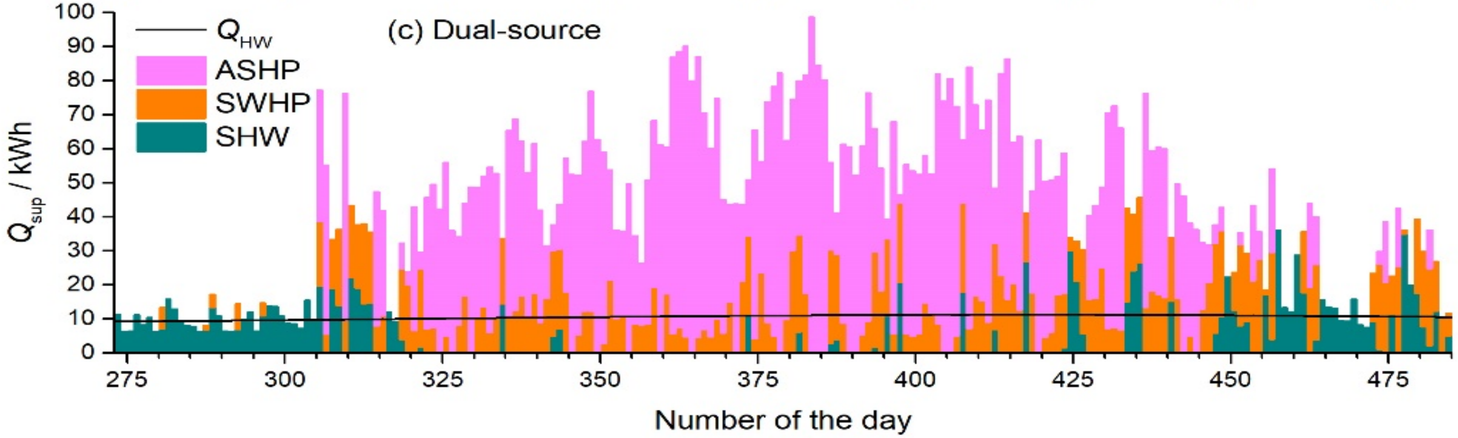
Dual-source

Results

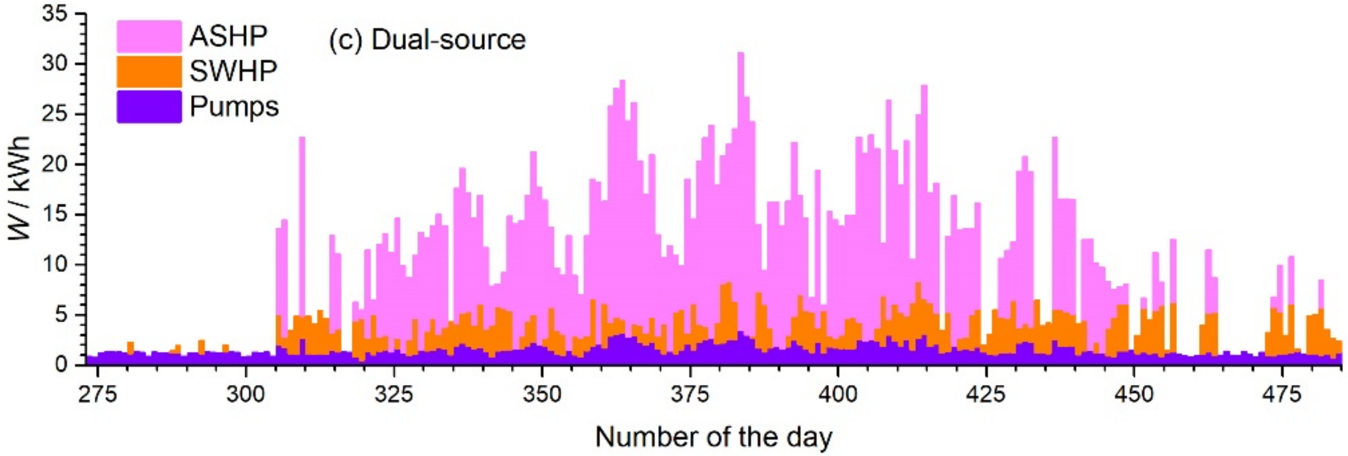
- T_{air} and tank water supply T_{hws} for space heating and hot water



- Heat supplied



- Electricity consumption

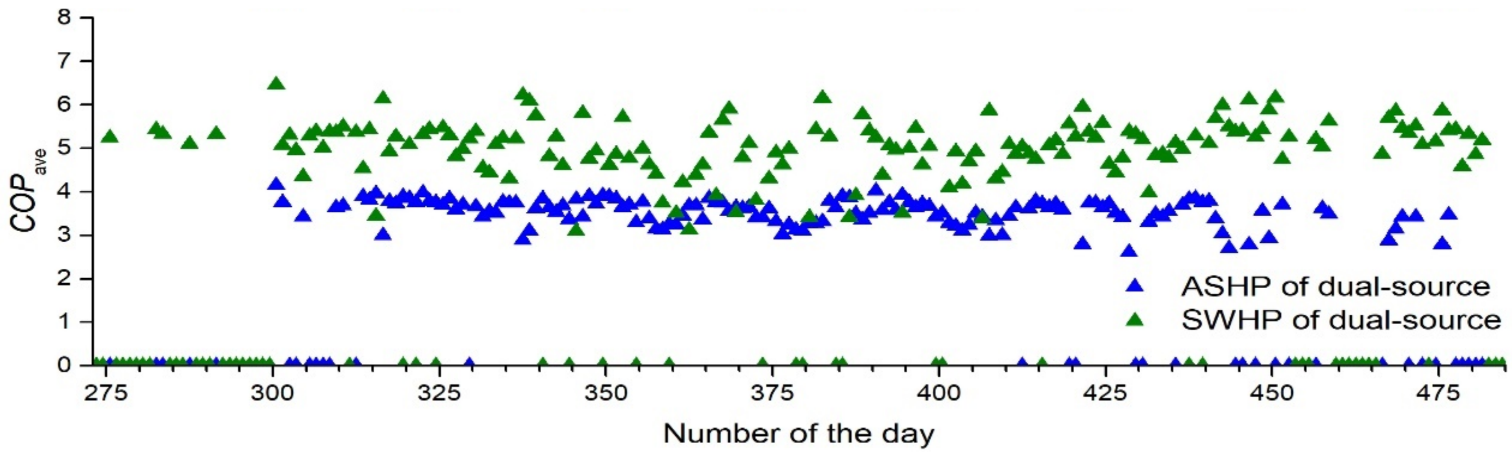


Daily averaged *COP* of Heat Pumps Daily *SPF* of Heating System

- **Daily averaged COP**

  ASHP module: 2.5-4.5

  WSHP module:3.0-7.0



- **SPF (seasonal heating supply/ seasonal electricity consumed)**

  2.9