The Study of Solar Combisystem Deployed in Aquatic Farm for Mitigating Hypothermia Damage during Cold Stream Event

太陽能集熱板暨熱泵複合式系統應用於寒害期間以降低魚塭之寒害損失

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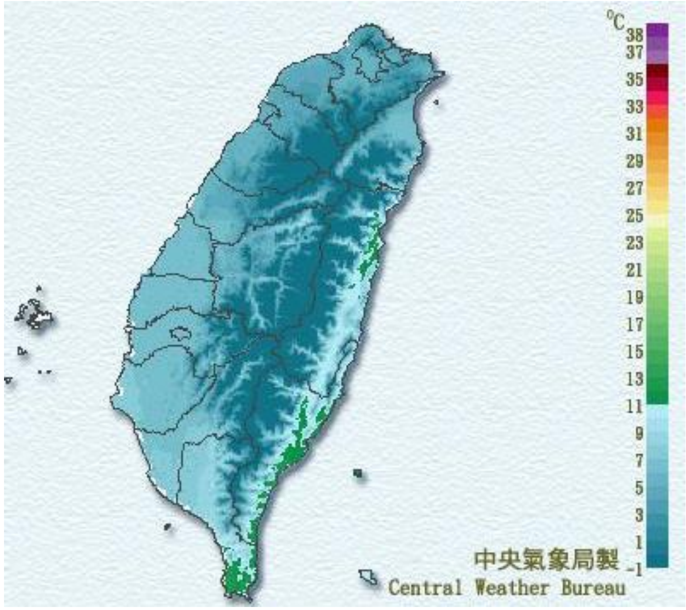
共同指導教授：張克勤 教授

日期：**2019/07/26**

Taiwan's climate

1



Tainan (120°E, 23°N)	**2016, Jan. 24** Temperature: 5~7 °C	Dead fish

Cold stream leads to an unprecedented financial loss.

Farmed organism

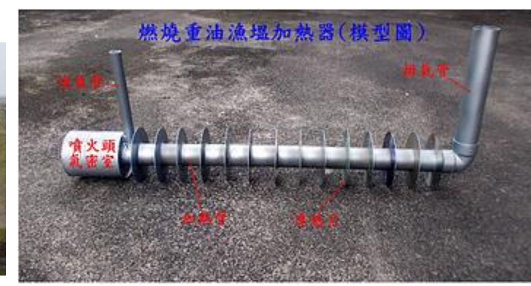
2

	Milkfish[1]	Whiteleg Shrimp [2,3]
Moderate temperature	25 °C ↑	18 – 30 °C
Reduce activity temperature	14 °C ↓	18 °C ↓
Lead to die temperature	10 °C ↓	9 °C ↓

Milkfish

Shrimp

Shelters [4]



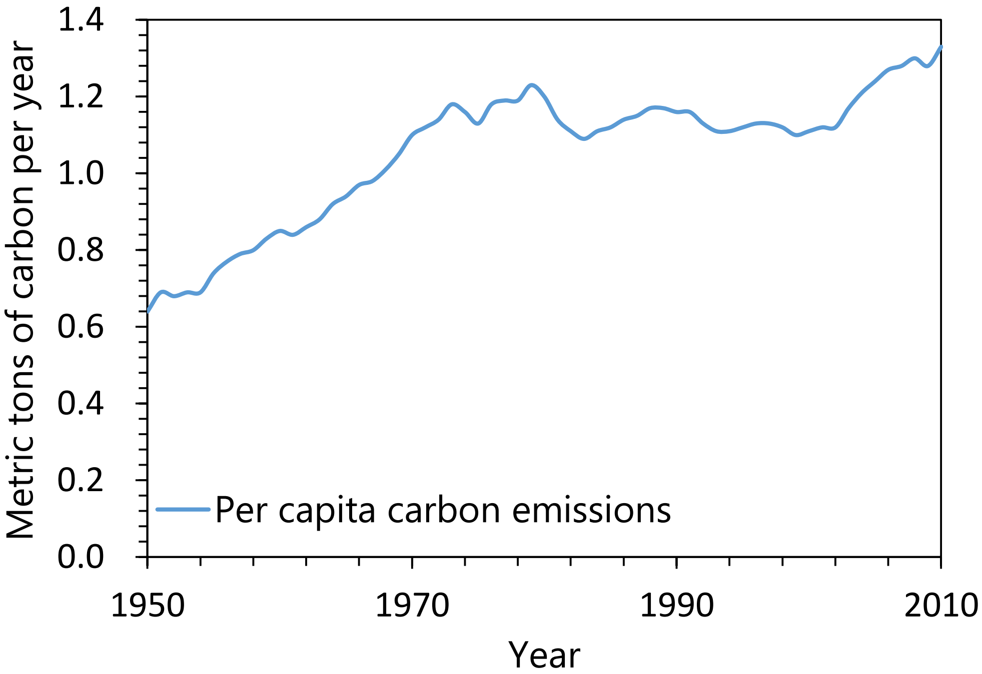
Heavy oil [5]

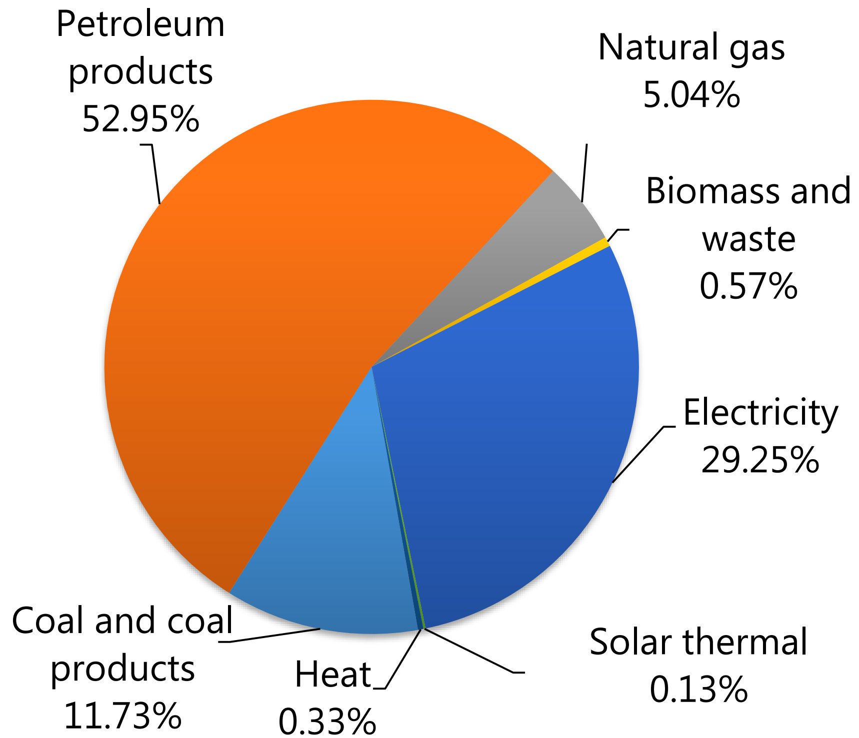
Need to keep the water temperature above 10°C

[1] 鄉情. 南台灣的家魚-虱目魚. 台灣月刊.
[2] 蘇甘棠. 2007.
[3] 陳弘成. 白蝦養殖與管理方式. 養魚世界.
[4] https://tnews.cc/06/ADOShowBigPhoto.asp?from=D158063
[5] https://ppt.cc/fExjpx

Nonrenewable energy [6,7]

3



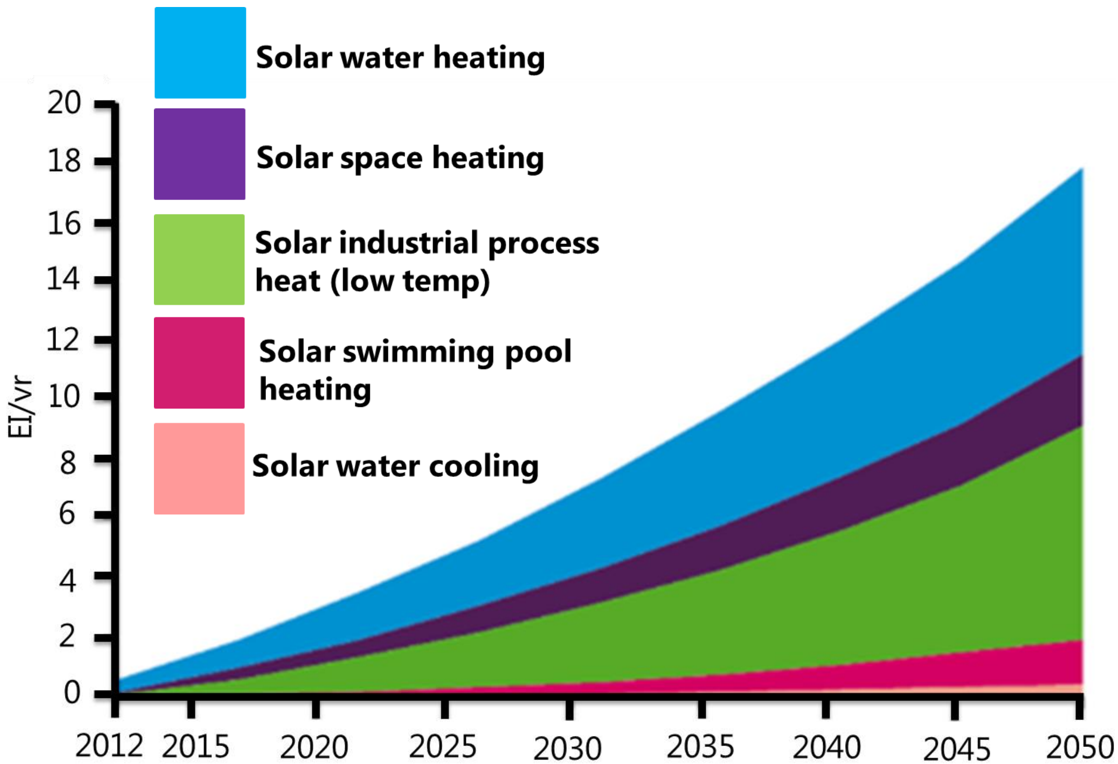


Enhance the use of renewable energy

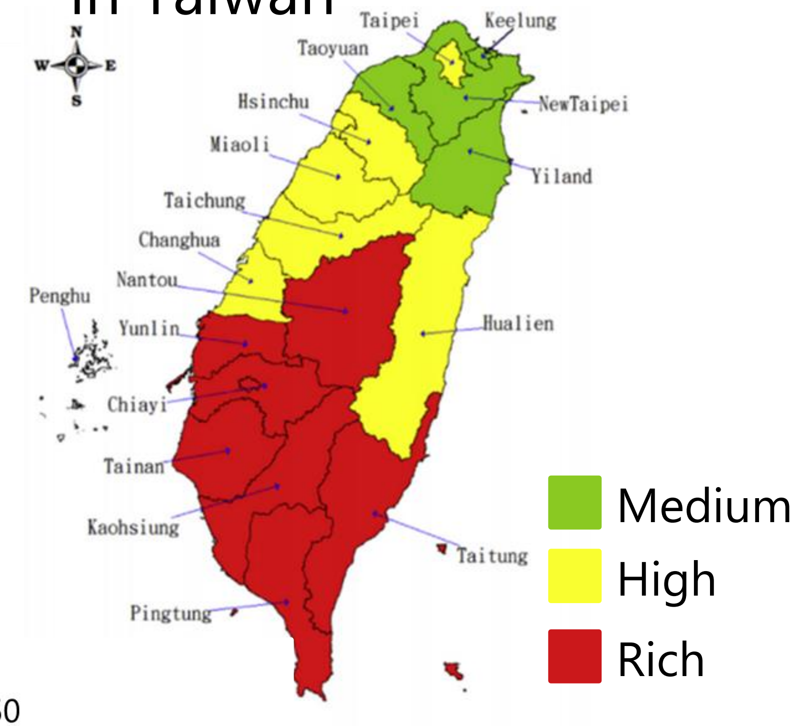
[6] Boden TA, Marland G, Andres RJ. 2009.
[7] Beurea of Energy MoEA. 2017.

Renewable energy [8,9]

4



- Solar radiation zoning in Taiwan

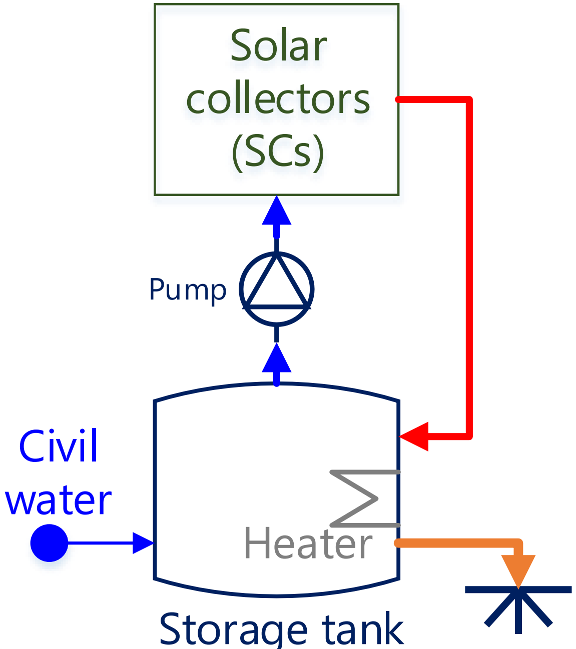


Southern Taiwan is suitable for solar thermal system.

[8] Energy I, Change C. 2015.
[9] Ko L, Wang J-C, Chen C-Y, Tsai H-Y. 2015

Solar combisystem

- Conventional solar heating system



- Auxiliary heat source[10]
  - ✓ Boiler → fossil fuel consumption
  - ✓ Electric heater → lower efficiency
  - ✓ Ground heat exchanger→ higher cost
  - ✓ Heat pump (HP) → best choice

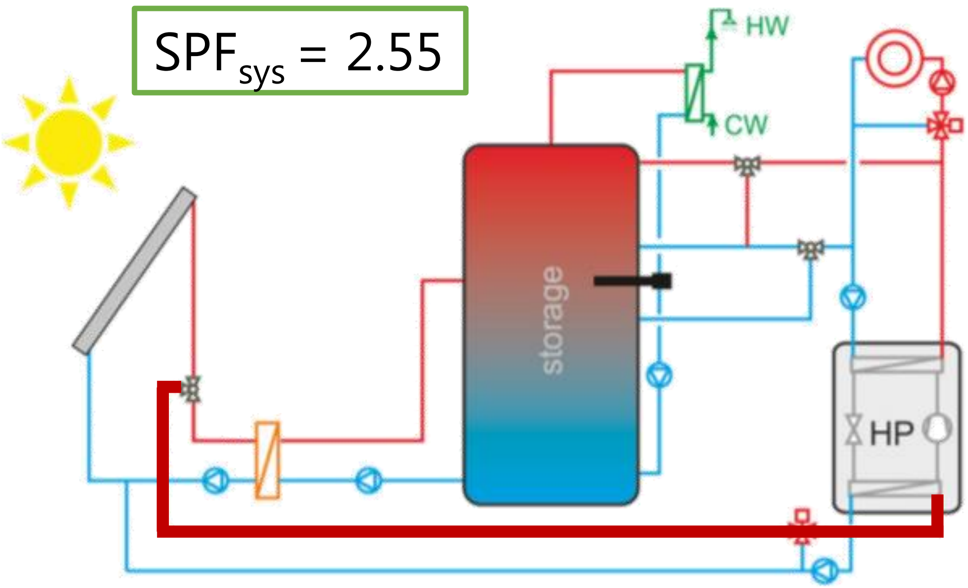
HP as an auxiliary for solar heating system can achieve 70% energy saving .[11]

[10] Buker MS, Riffat SB. 2016.
[11] Panaras G, Mathioulakis E, Belessiotis V. 2013

Layout of solar combisystem [12]

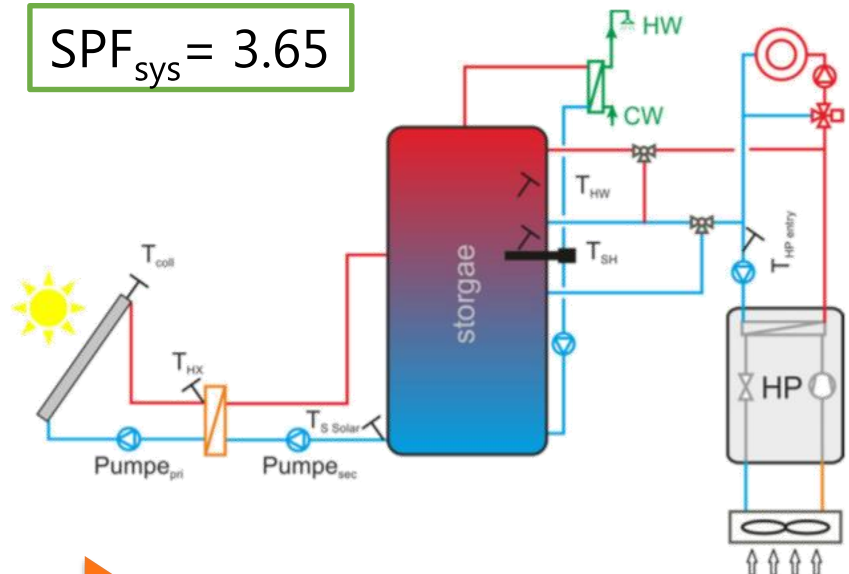
- Serial solar HP system

SPF_{sys} = 2.55



- Parallel solar HP system

SPF_{sys}= 3.65



Seasonal Performance Factor

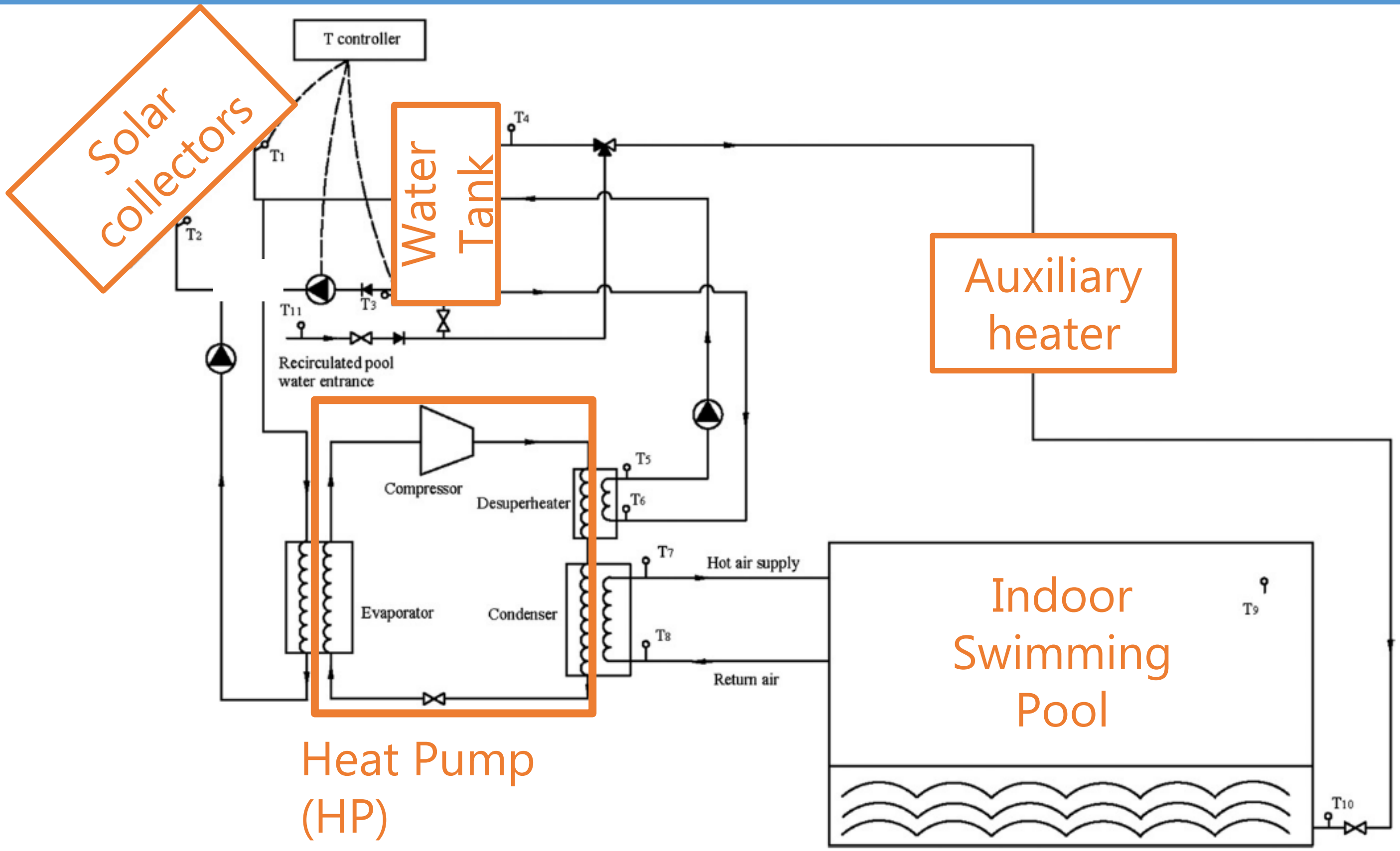
$$SPF = \frac{Q_{total}}{E_{total}}$$

Q_{total} : heat provided by heating system
E_{total} : power consumed by system

Parallel solar HP system
- ✓ Low complexity
- ✓ Robust
- ✓ High efficiency

[12] Carbonell D, Haller M, Frank E. 2014

Application of solar combisystem [13]



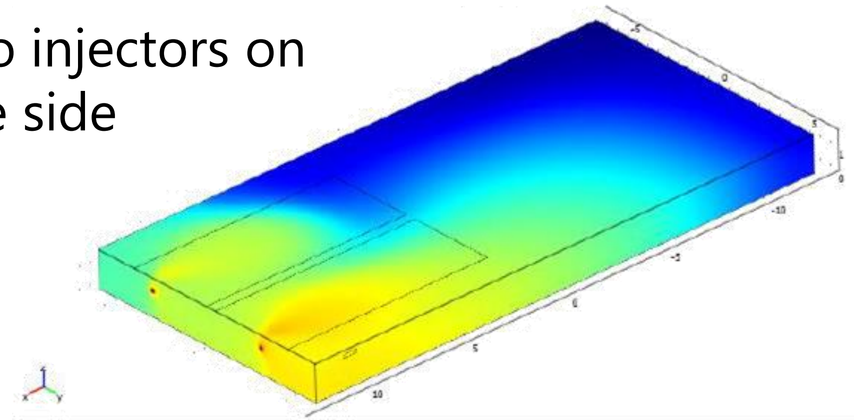
Solar combisystem is applied to swimming pool.

[13] Chow TT, Bai Y, Fong KF, Lin Z. 2012

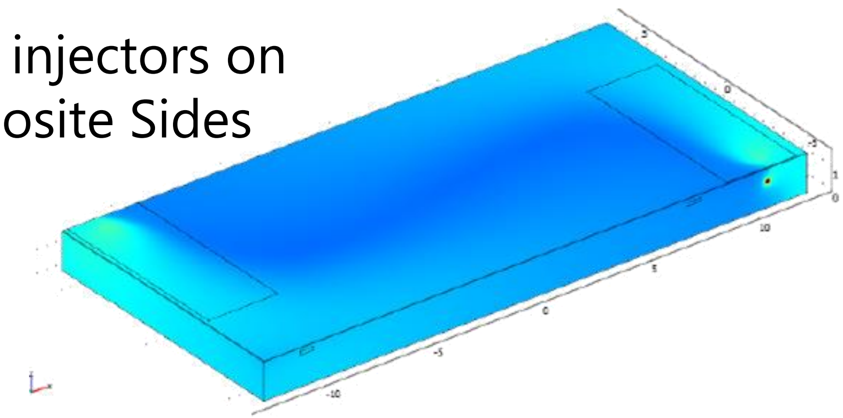
Application of water pool in simulation [14]

Pool size	
Width	12.5 m
Length	25 m
Depth	1.48 m

Two injectors on one side



Two injectors on Opposite Sides



- ✓ Simulate temperature distribution in CFD software
- ✓ Comparisons items in CFD software

[14] Roldan CI, 2014

Scenario of the water pool

Authors	Geometry	Cells	Items of comparisons
Gao et [15]		20,786	✓ Inlet velocities
Assari e [16]	1(		and outlets
Ievers and Lin [17]	1		ight to ets d outlet
Lavan and Thompson [18]			✓ Ratio of length to diameter
Kenjo et al. [19]	121cm, 57.7cm,--	Experiment	✓ Height of the inlets

Items of comparisons

- ✓ Inlet:
  - ✓ location
  - ✓ geometry
  - ✓ velocities (mass flowrate)
- ✓ Height of the inlets and outlets
- ✓ Ratios of the tank height to diameter

[15] Gao W, Liu T, Lin W, Luo C. 2011
[16] Assari MR, Basirat Tabrizi H, Savadkohy M. 2018
[17] Ievers S, Lin W. 2009
[18] Lavan Z, Thompson J. 1977
[19] Kenjo L, Inard C, Caccavelli D. 2007

Motivation

Agriculture

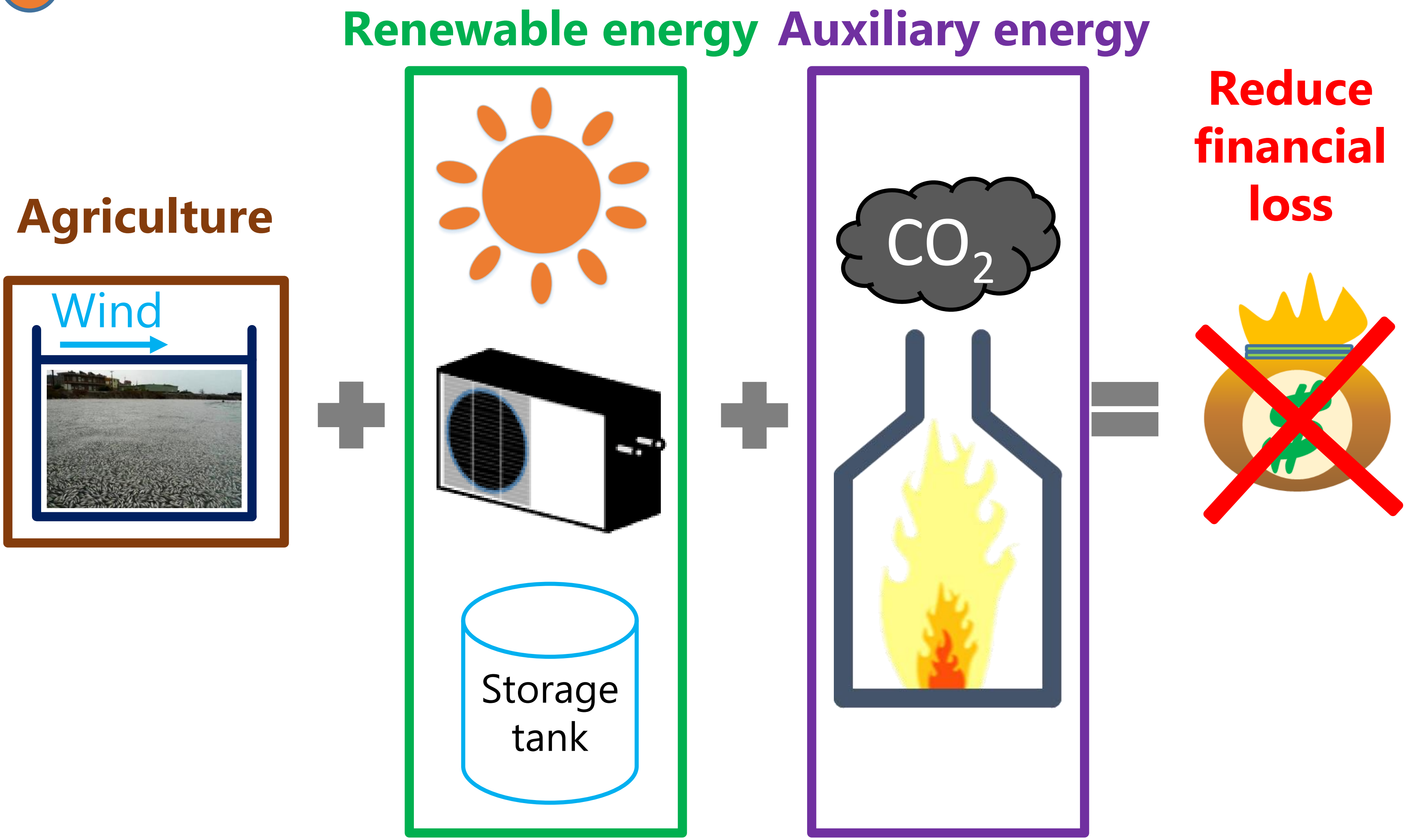
+

Renewable energy

=

Reduce financial loss

Objective


Renewable energy
Auxiliary energy
Agriculture
Wind
Storage tank
CO_2
Reduce financial loss

Numerical software - STAR-CCM+

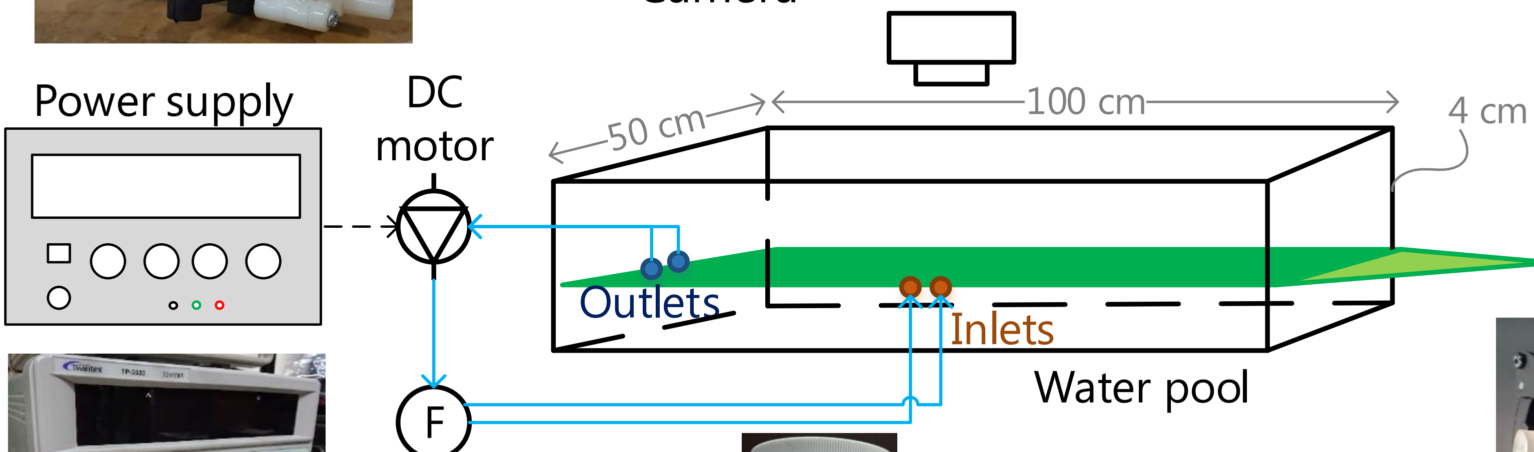
- A computational fluid dynamics software
- Finite volume method
- Simulate temperature distribution

Experimental apparatus - Particle image velocity (PIV)

Adjustable continuous laser energy
Wavelength: 532 nm
Beam diameter<1.0mm
Divergence<1.0 mrad

DC motor

Camera



Laser

Power supply

Seeding particles
Hollow Glass Spheres
Glass oxide
8~12 μm

Len

Experimental apparatus of validation

Location : 歸仁校區

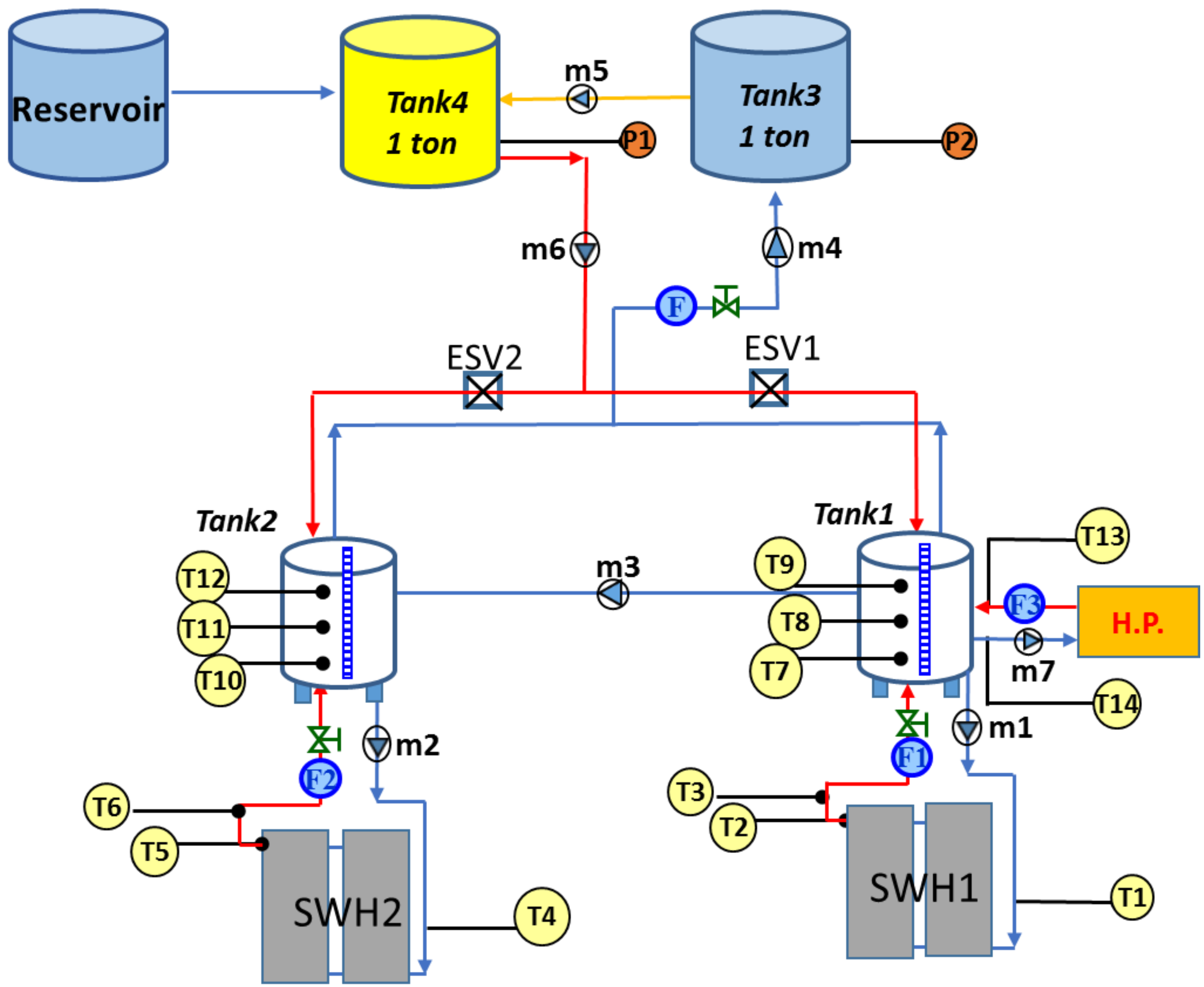
Solar combisystem

Heliograp

Psychrometer

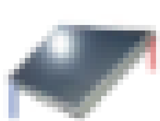
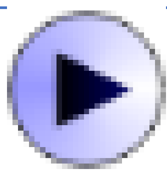
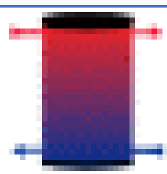
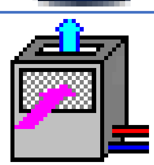
Lab-scale combination heating system layout

Time	Time
R collector Tout (Temp control)	T2
R collector Tout (Q)	T3
R collector Tin (Q)	T1
L collector Tout (Temp control)	T5
L collector Tout (Q)	T6
L collector Tin (Q)	T4
Heat pump in	T13
Heat pump out	T14
R Tank bottom	T7
R Tank middle	T8
R Tank top	T9
L Tank bottom	T10
L Tank middle	T11
L Tank top	T12
R collector flow meter	F1
L collector flow meter	F2
Heat pump flow meter	F3
L tank pressure	P1
R tank pressure	P2

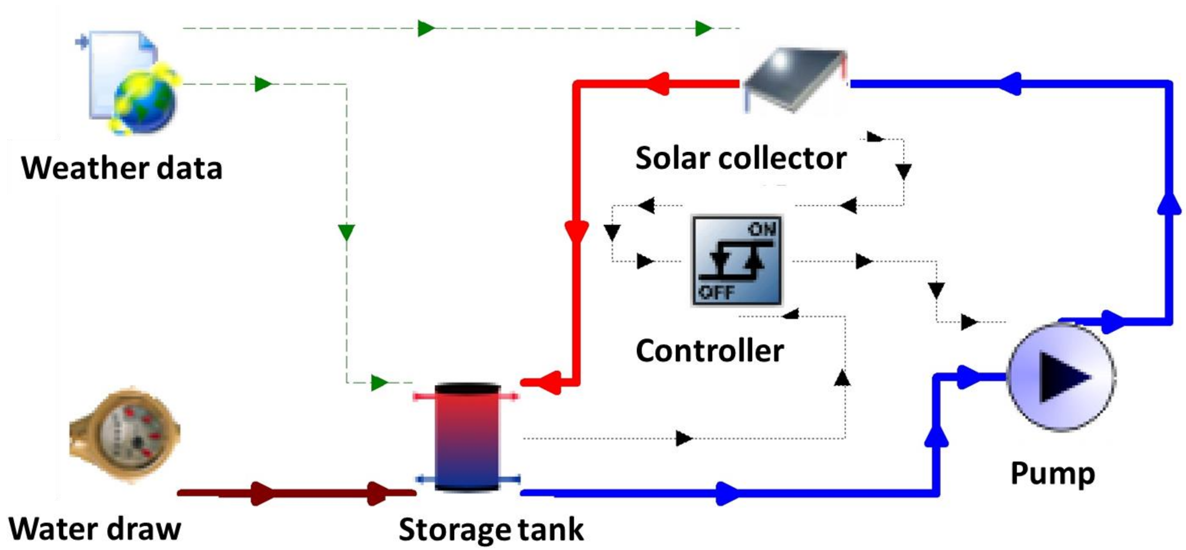


Numerical software - TRNSYS

- TRNSYS 17 is an extremely flexible graphically based software environment used to simulate the behavior of transient systems.

	Solar collector
	pump
	Storage tank
	Heat pump

- Solar heating system



Methodology

Calculate the heat demand in the cold days

Model solar combisystems by TRNSYS Validate by the experiments	Model lab-scale pool in STAR-CCM+ Validate STAR-CCM+ by PIV
Simulate heating system	Simulate aquatic farm in STAR-CCM+
System comparisons	Scenario analysis parameters Optimize aquatic farm by Taguchi method

Lab-scale system

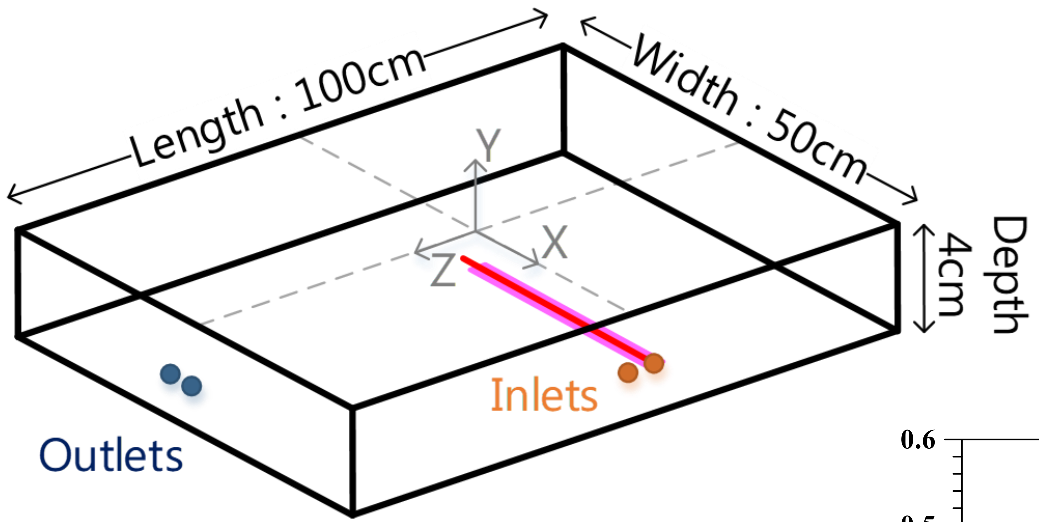
TRNSYS 17

- ✓ Hot water
- ✓ Mass flowrate
- ✓ Temperature

STAR-CCM+

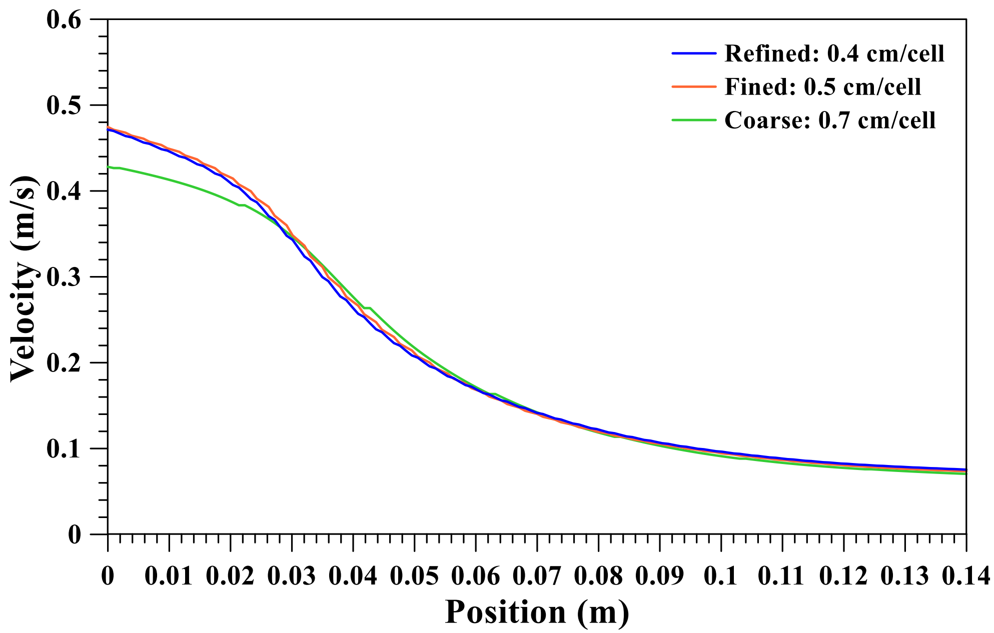
PIV

Validation of STAR-CCM+

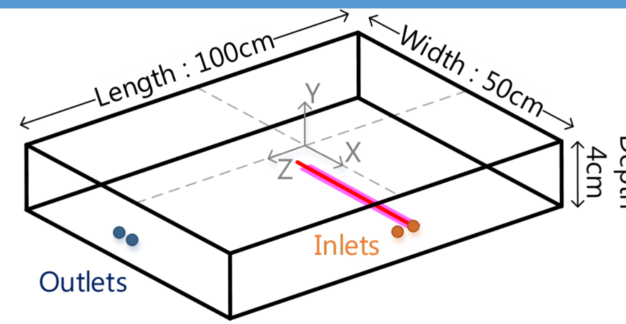


- ✓ Steady model
- ✓ Gravity
- ✓ Coupled flow and energy
- ✓ k-ω turbulence

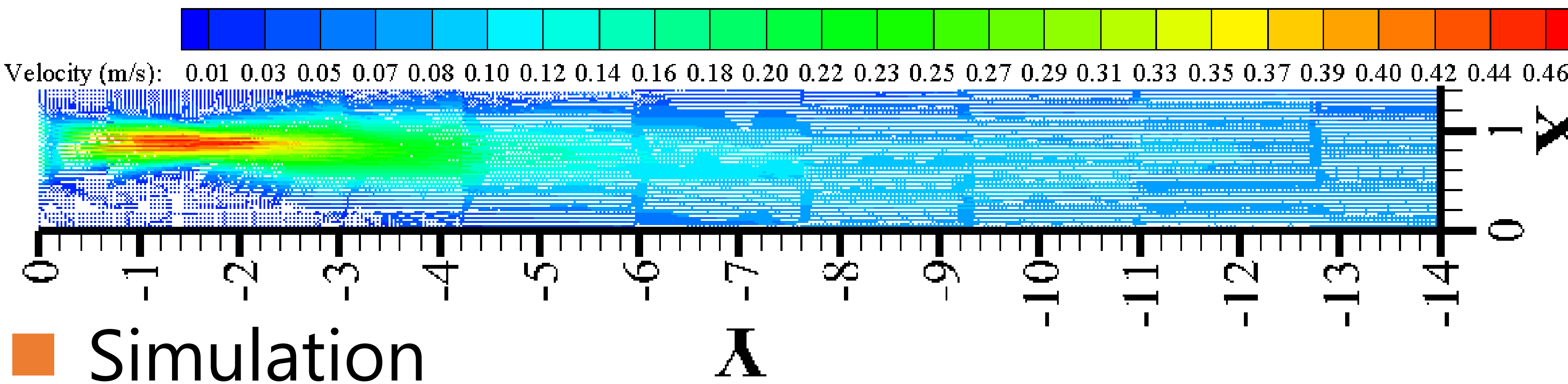
	Boundary type
Inlets	Velocity inlet
Outlets	Flow-split outlet
Floor	Wall
Side walls	Wall
Surface	Wall



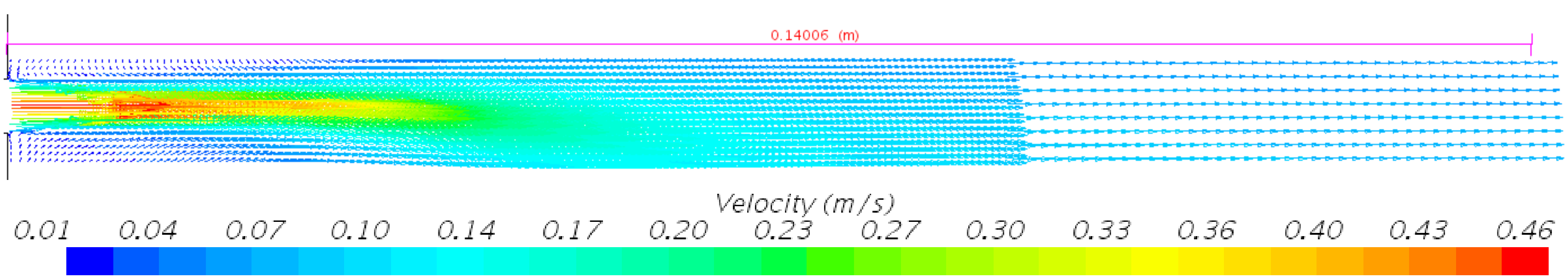
Validation of STAR-CCM+



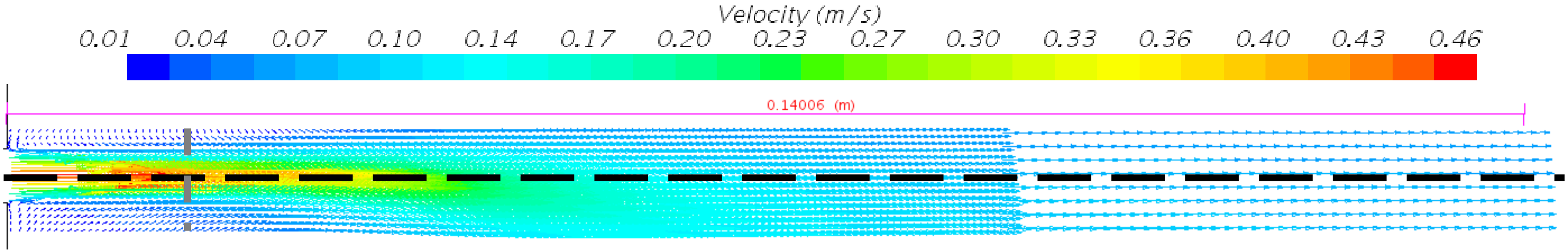
- Experiment

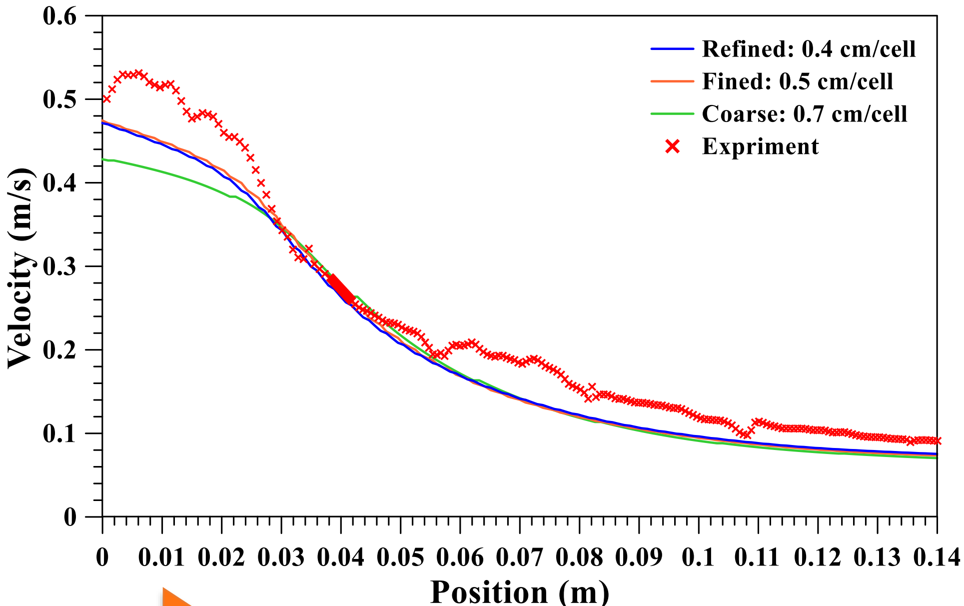


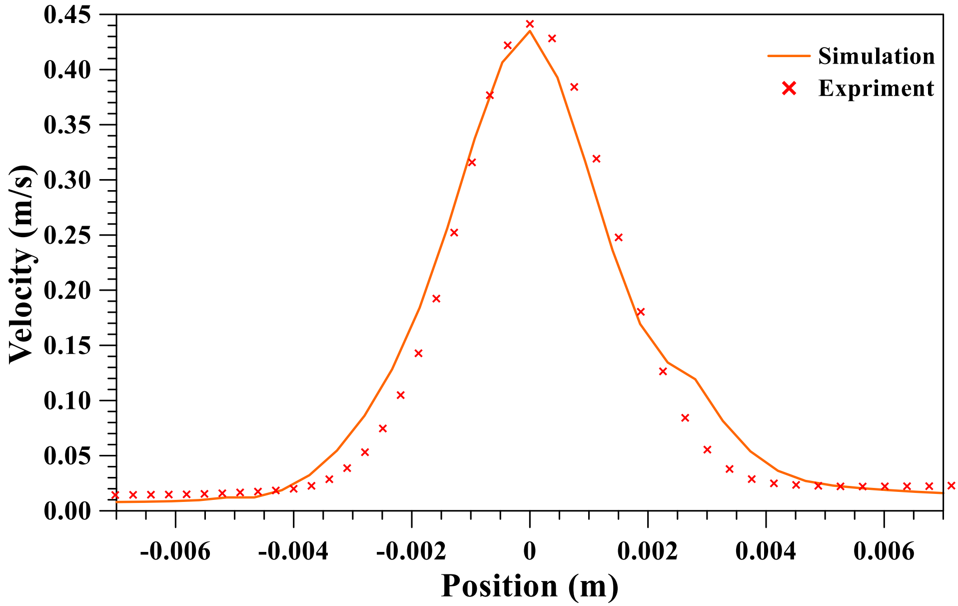
- Simulation



Validation of STAR-CCM+

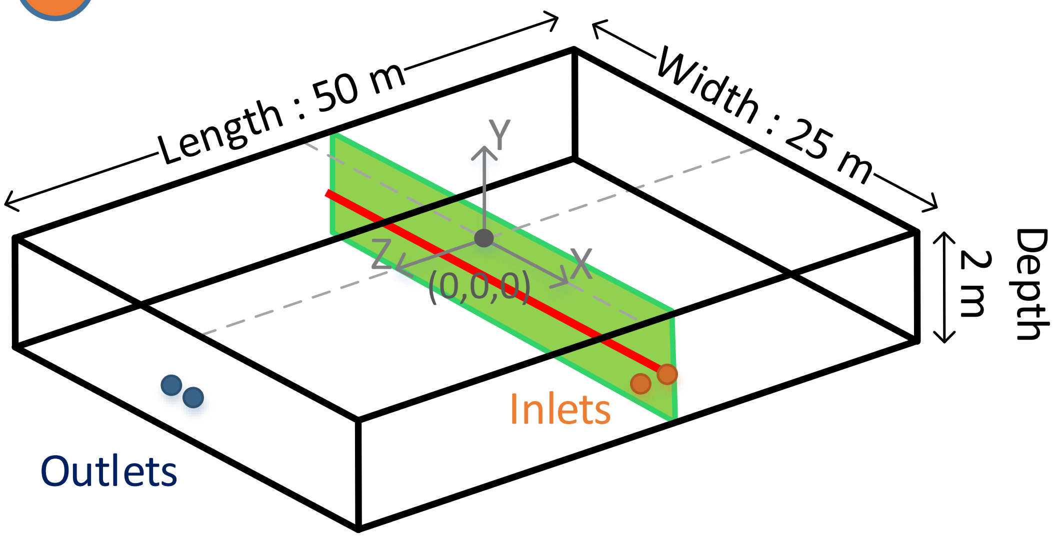






Validate simulation.

Simulation of aquatic farm



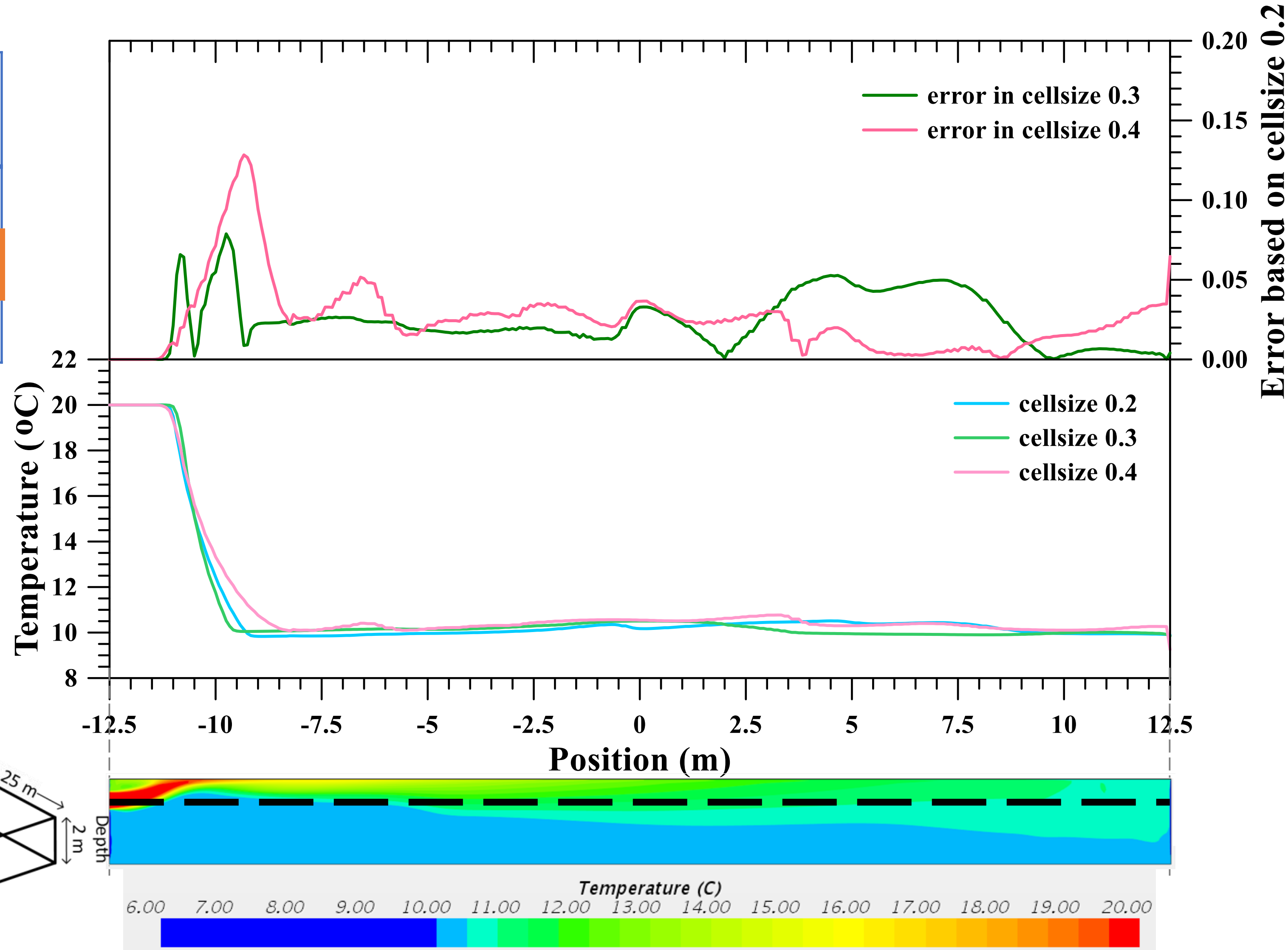
Cell size (m)	Refined mesh (m)			Cell elements
	50%	*25%*	*10%*	
0.4	0.2	0.1	0.04	1,067,457
0.3	0.15	0.075	0.03	1,733,201
0.2	0.1	0.05	0.02	4,804,209

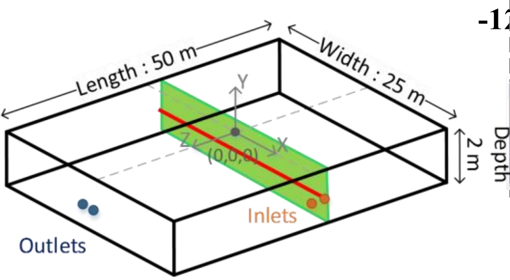
✓ Unsteady model ✓ Gravity ✓ k-ω turbulence ✓ Coupled flow and energy

	Boundary type	Description
Inlets	Mass flow inlet	$\dot{m} = 25$ kg/s; I = 0.0411; $\ell = 0.01$ m T = 20 ℃
Outlets	Flow-split outlet	Split ratio = 1
Floor	Wall	Constant temperature: T = 10 ℃
Side walls	Wall	Table: Temperature change with depth
Surface	Wall	Ambient temperature = 6 ℃ Convection heat transfer = 10 W/m^2-K

Simulation of aquatic farm

	Cell size (m)
	0.4
	0.3
	0.2





Parameter analysis

No.	Parameters		Survival zone (m^3)	%	Difference %
1	Distance between inlet 1 and inlet 2	Inlet2= 0.5	1936.18	77.73%	9.20%
		Inlet2= 12.5	1707.12	68.53%	
2	Two inlets of the height	-0.5	1936.18	77.73%	7.94%
		-1.5	2133.86	85.66%	
3	Outlets positions	Same side	1936.18	77.73%	12.60%
		Opposite side	1622.30	65.13%	
4	Inlets velocity	V1= 0.8 m/s	1709.80	68.64%	3.94%
		V2= 0.2 m/s	1611.61	64.70%	
5	Barrier length	length=15m	1273.12	51.03%	18.38%
		length=45m	811.85	32.65%	
6	Barrier position	Distance= 10m	1264.80	50.77%	14.47%
		Distance= 20m	1625.18	65.24%	
7	Barrier thickness	Depth= 0.75m	1671.17	67.09%	0.47%
		Depth= 1.5m	1682.76	67.55%	
8	Barrier numbers	1*30	1518.40	60.96%	0.98%
		10*3	1494.07	59.98%	

Survival zone: 10.5 °C ↑ zone

$$\% = \frac{\text{survival zone}}{\text{total zone}}$$

Taguchi method

Orthogonal array

Reduce experiments times through optimum settings of control parameters.

4 parameters & 3 levels → **81 sets** → Taguchi method → **9 sets**

Series of Experiment	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

S/N ratio

- Smaller-the-better
- Larger-the-better
- Nominal-the-better

$$S/N = -10\log\left[\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2}\right]$$

n: the number of tests

y_i: the value of the indicators

Taguchi method

A	Two inlets of the height (m)
B	Outlets positions (--)
C	Barrier length (m)
D	Barrier position (m)

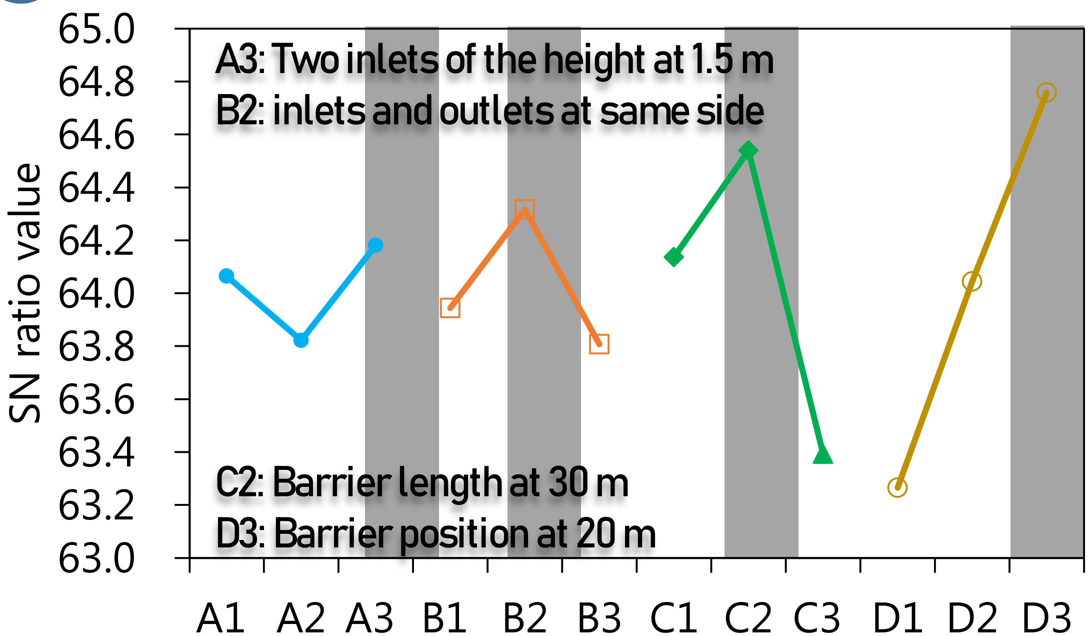
Exp.	A	B	C	D	Survival zone (m^3)	%	S/N Ratio
1	1	1	1	1	1469.36	0.59	63.34
2	1	2	2	2	1757.58	0.71	64.90
3	1	3	3	3	1576.86	0.63	63.96
4	2	1	2	3	1777.23	0.71	64.99
5	2	2	3	1	1369.07	0.55	62.73
6	2	3	1	2	1538.44	0.62	63.74
7	3	1	3	2	1495.30	0.60	63.49
8	3	2	1	3	1846.07	0.74	65.32
9	3	3	2	1	1535.33	0.62	63.72

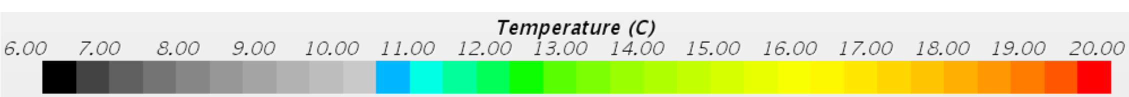
Parameters	(A)			(B)			(C)			(D)		
Level 1	A1	0.5	64.07	B1	Neighboring	63.94	C1	15	64.14	D1	10	63.27
Level 2	A2	1	63.82	B2	Same	64.32	C2	30	64.54	D2	15	64.04
Level 3	A3	1.5	64.18	B3	Opposite	63.81	C3	45	63.39	D3	20	64.76
max.- min.			0.36			0.51			1.15			1.49

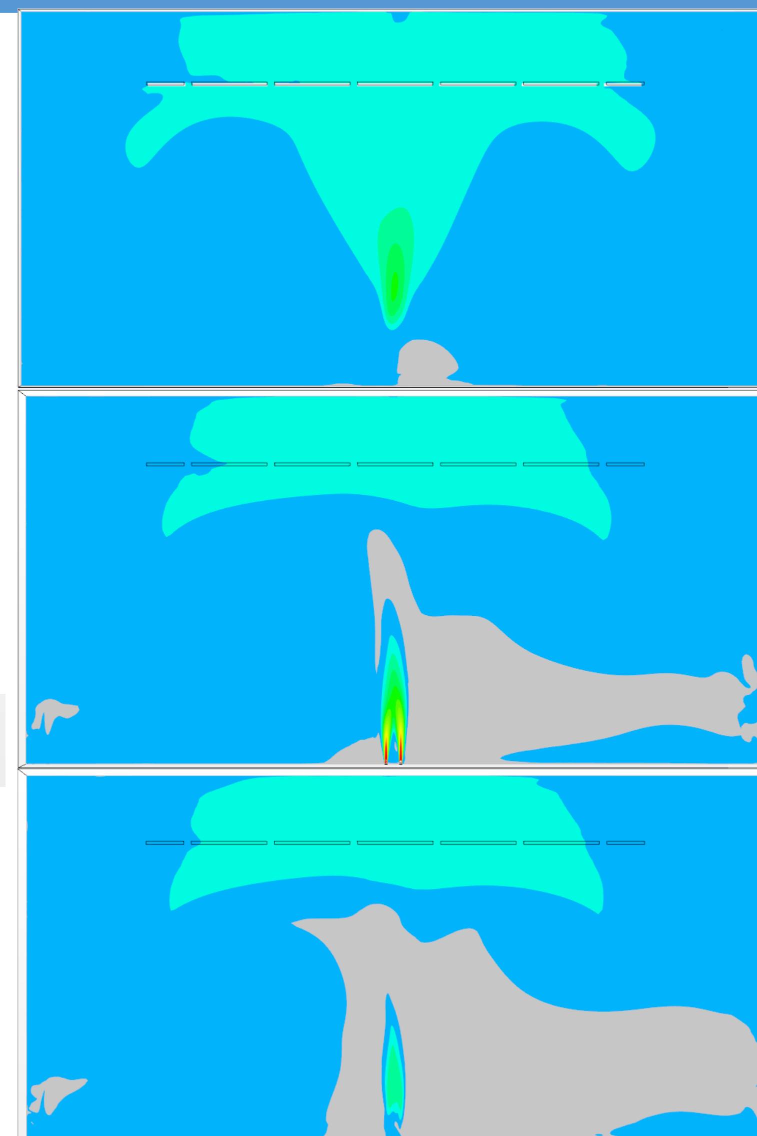
Optimized case

A3	1.5	B2	Same	C2	30	D3	20

Taguchi method

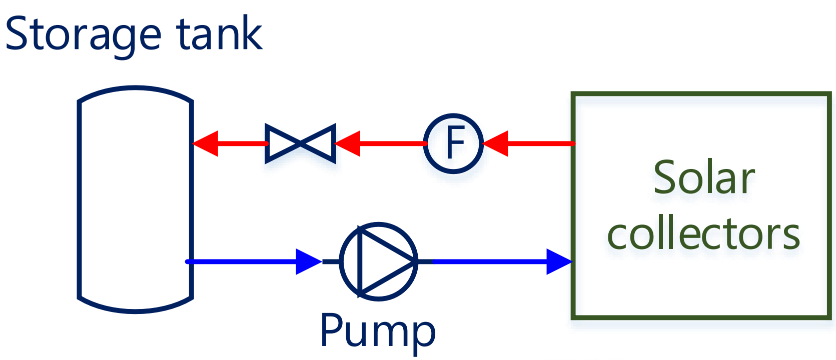


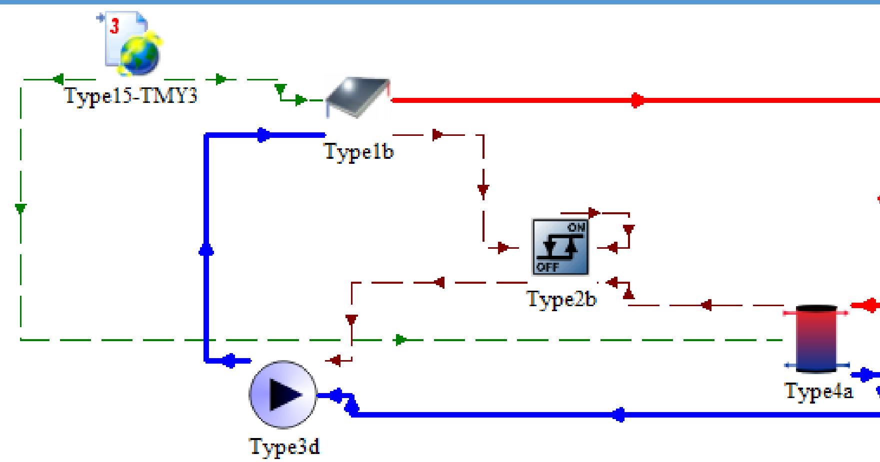




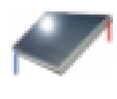
	SN ratio	Survival zone
Theoretical	65.73	1933.66
Simulation	65.21	1821.13
Error	0.80%	

Validated system (1) - Solar Water Heating System



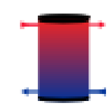


Solar collector



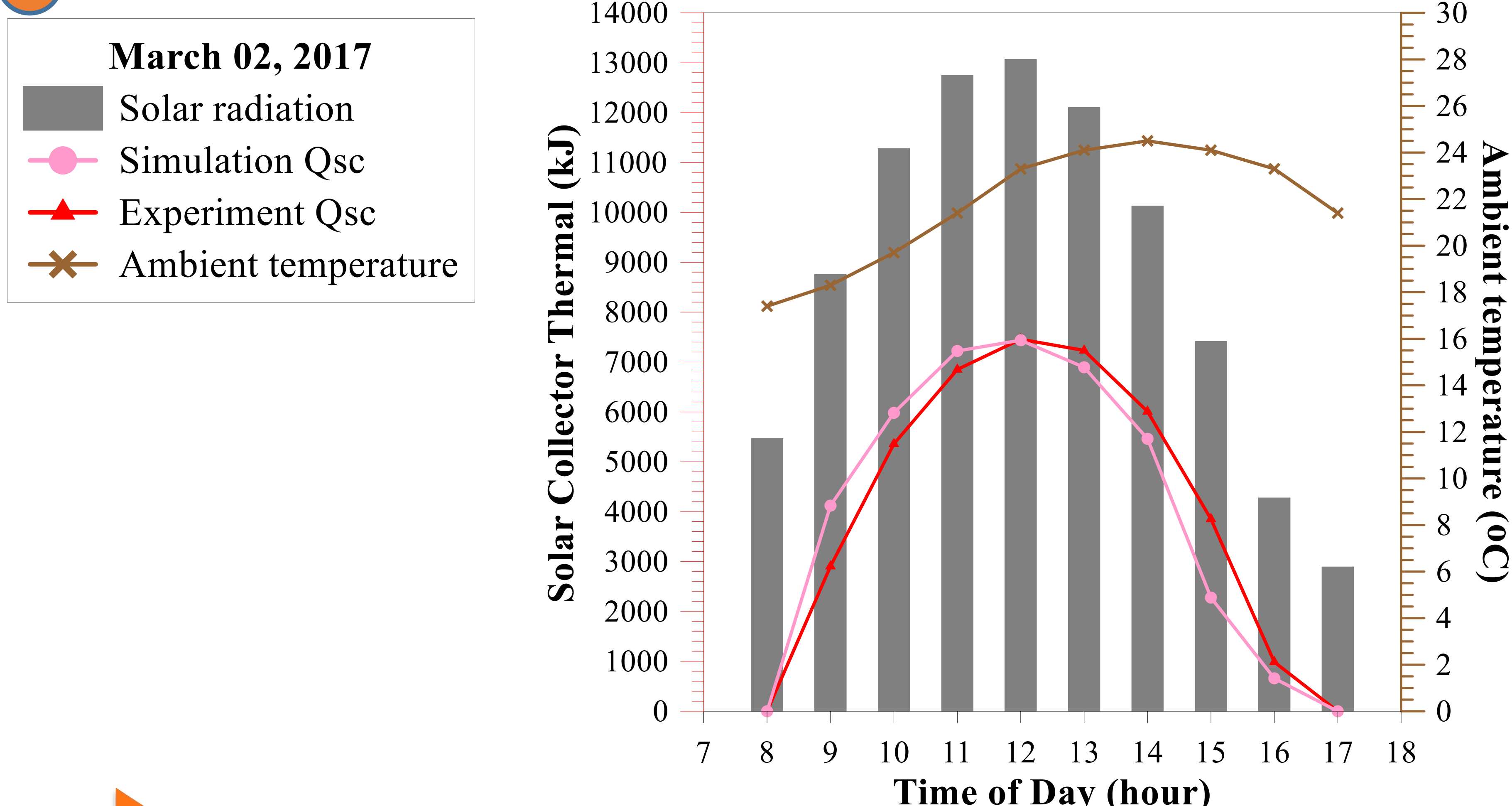
Parameter	Value
Collector area (m^2)	3.84
Intercept efficiency (--)	0.645
Efficiency slope ($kJ/hr.m^2.K$)	6
Efficiency curvature ($kJ/hr.m^2.K^2$)	0.02
1st-order IAM (--)	0.42

Storage tank



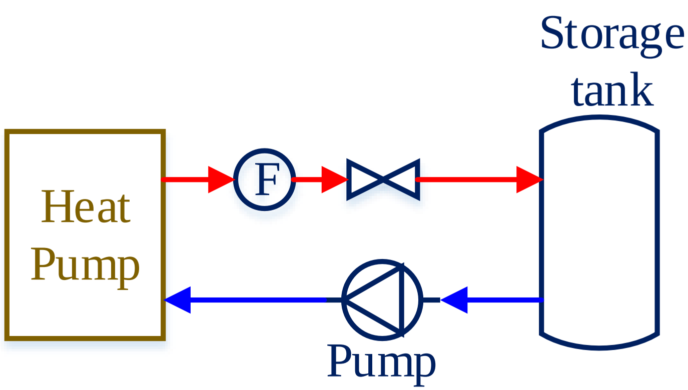
Parameter	Value
Cold side temperature(℃)	25
Initial nodal temperature (℃)	25
Tank volume (L)	460
Number of nodes (--)	3

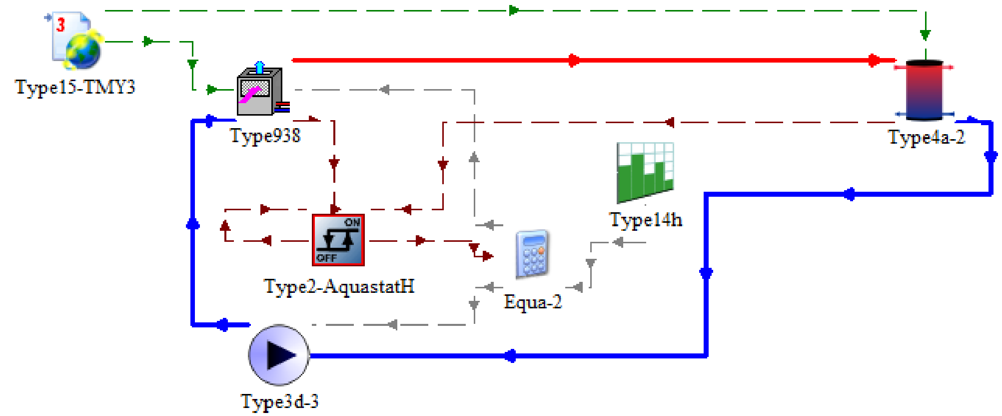
Validated system (1) - Solar Water Heating System



Validate parameters of solar thermal (Max error < 30%)

System Diagram (2) – Heat Pump Heating System

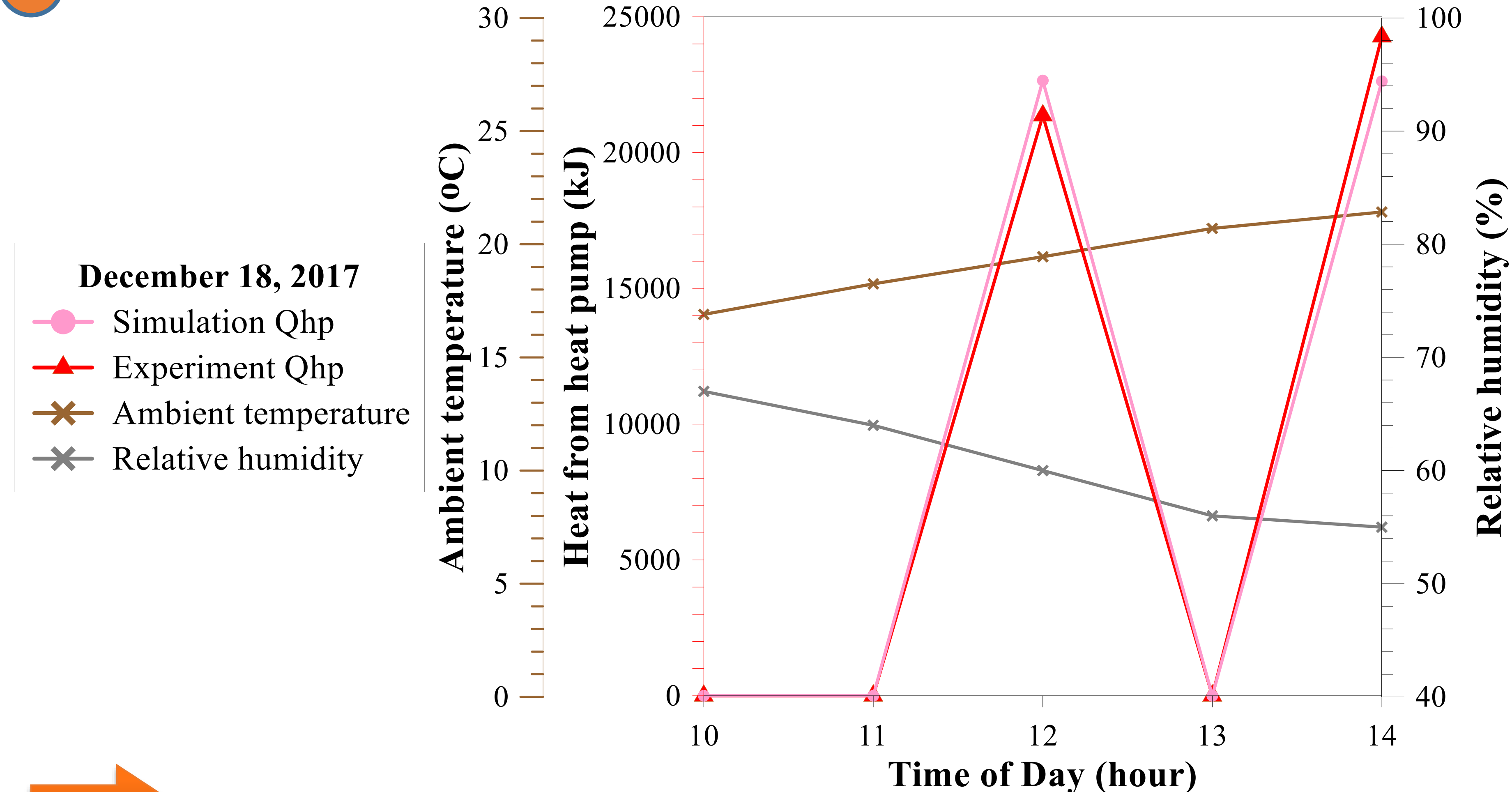




- **Heat pump**

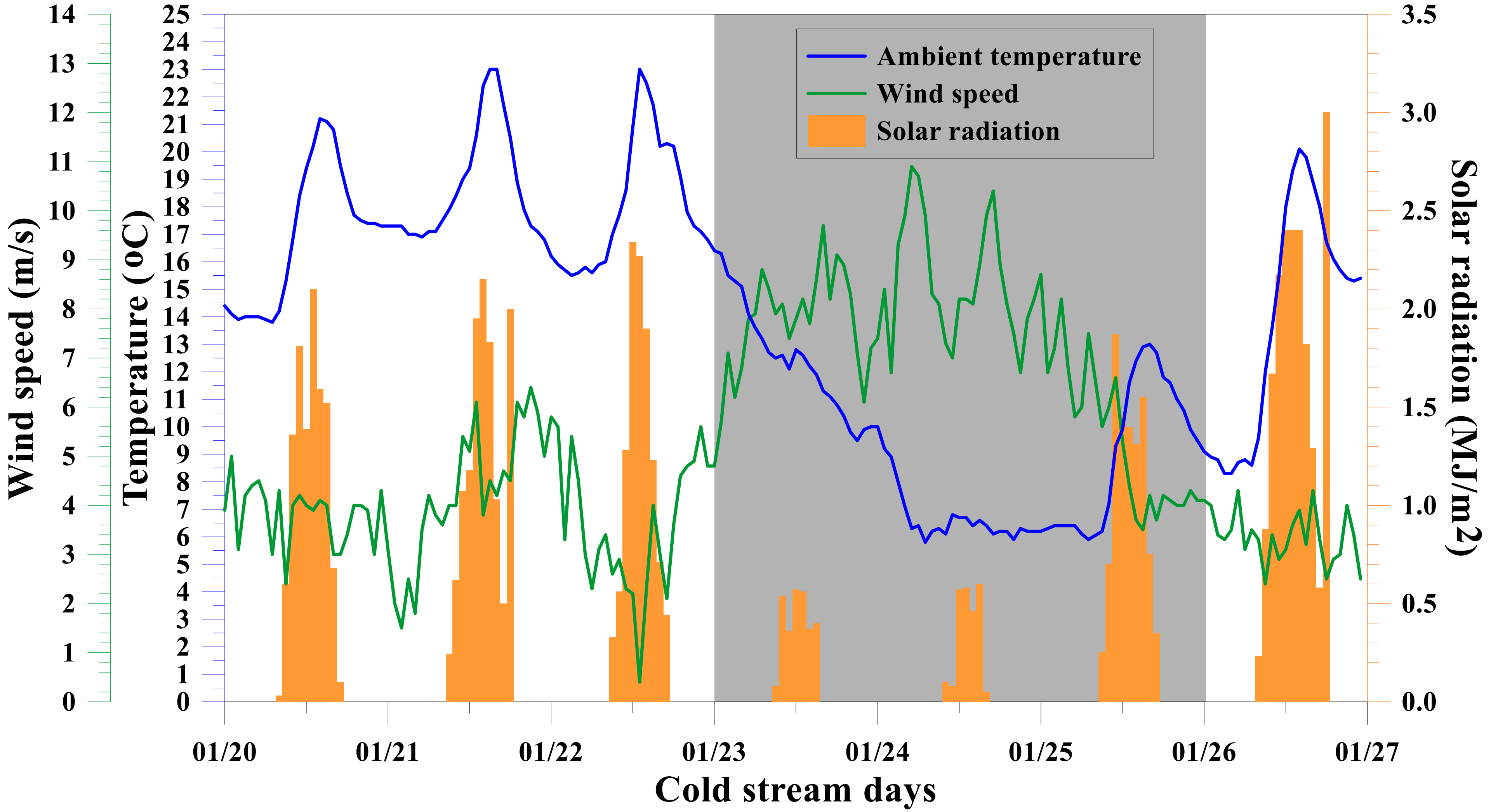
Parameter	Value	Unit
Rated compressor power	1.7	kW
Rated heat capacity	7	kW
Total air flow rate	717	L/s
Blower power	662	kJ/hr

System Diagram (2) – Heat Pump Heating System

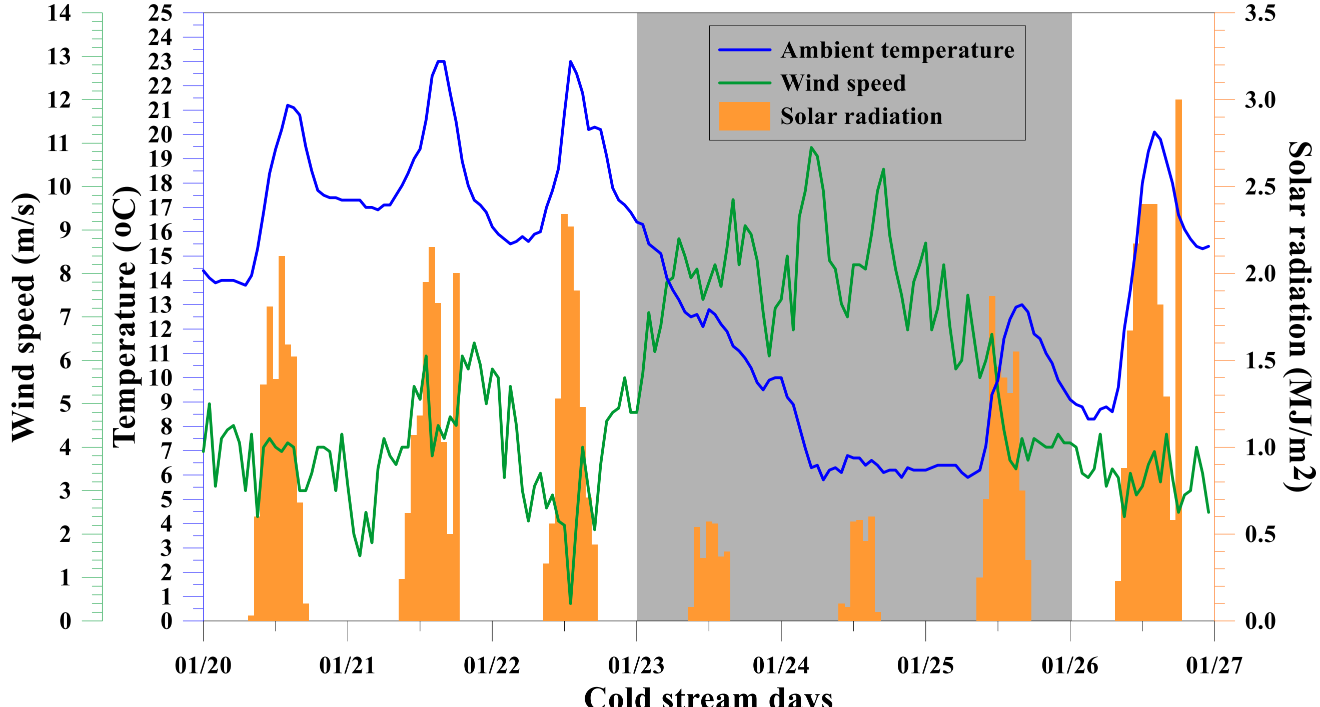


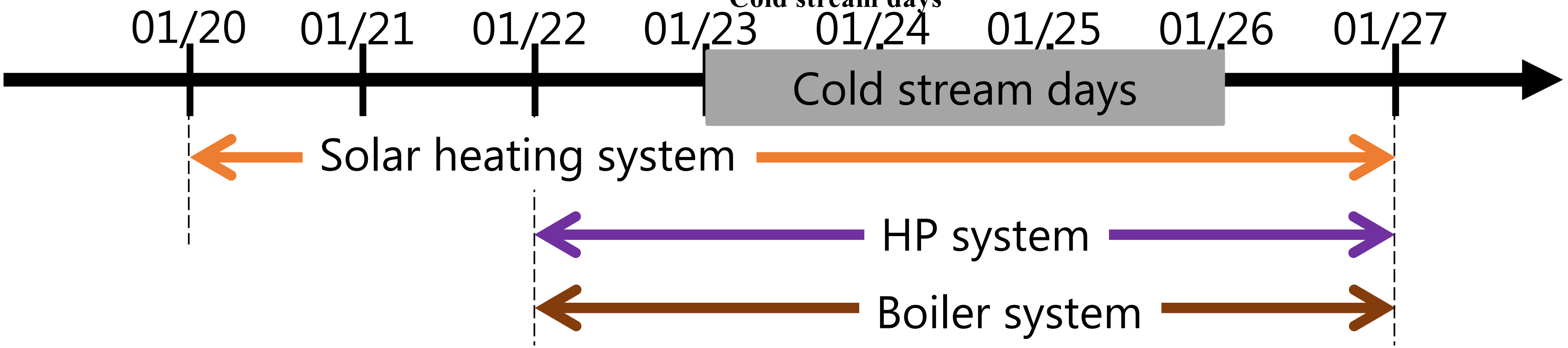
Validate parameters of HP (Max error < 10%)

Weather condition during cold stream in Jan. 2016



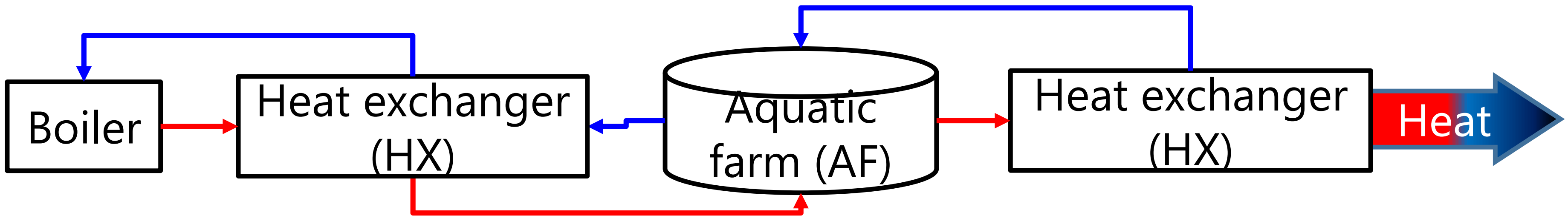
Heating schedule of heating system



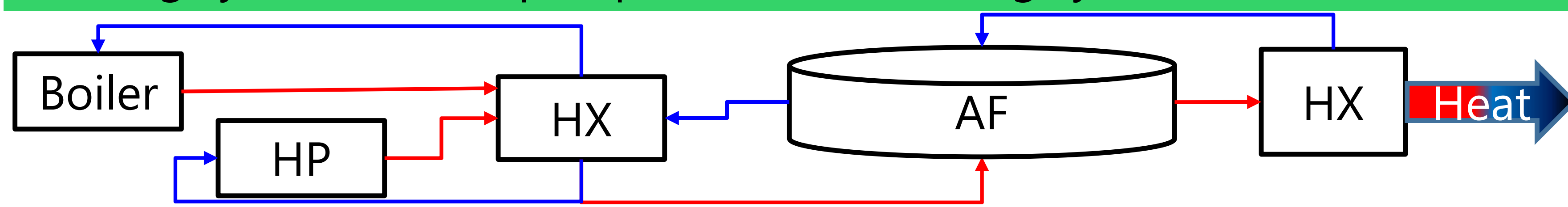


Scenario heating systems

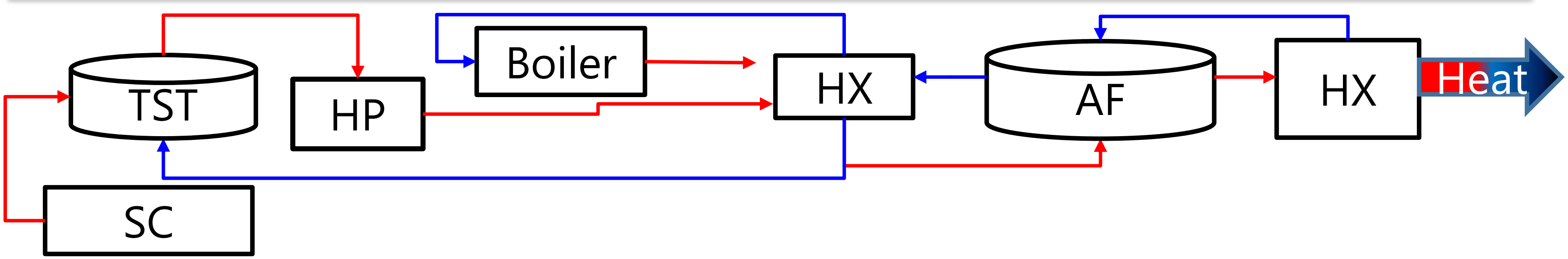
Heating system 1: Boiler heating system



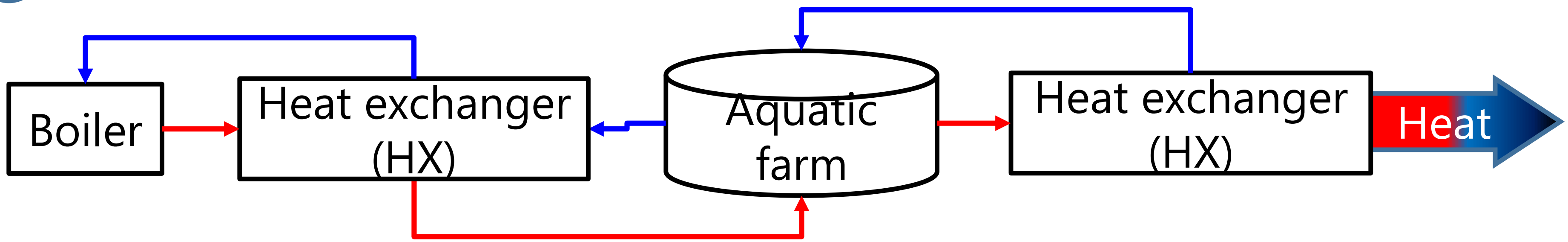
Heating system 2: Heat pump and boiler heating system

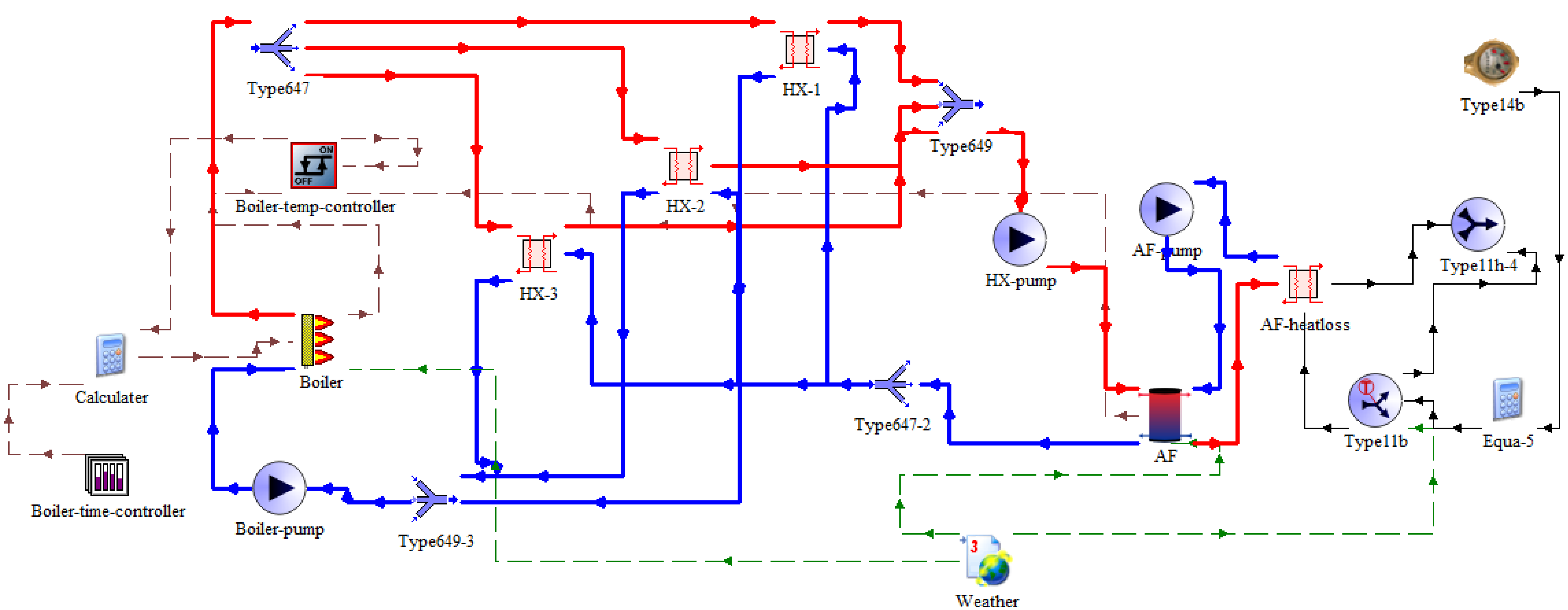


Heating system 3: Combination of SC-HP-B-Sys.

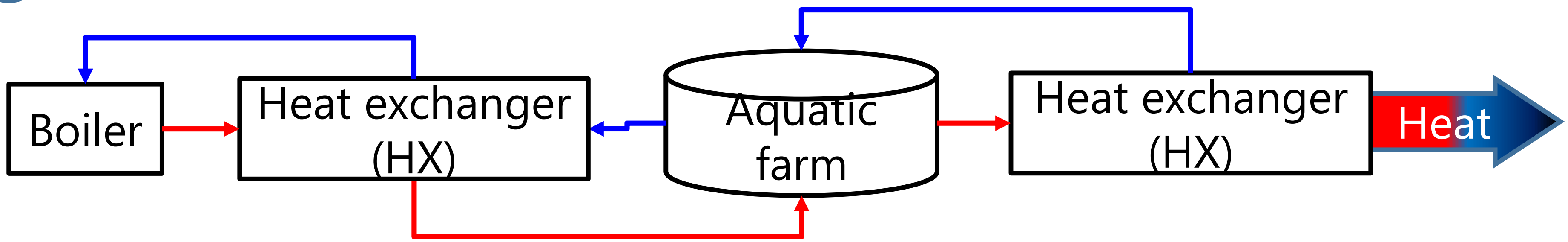


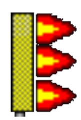
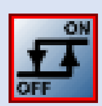
Heating system 1: Boiler heating system (290B-Sys.)



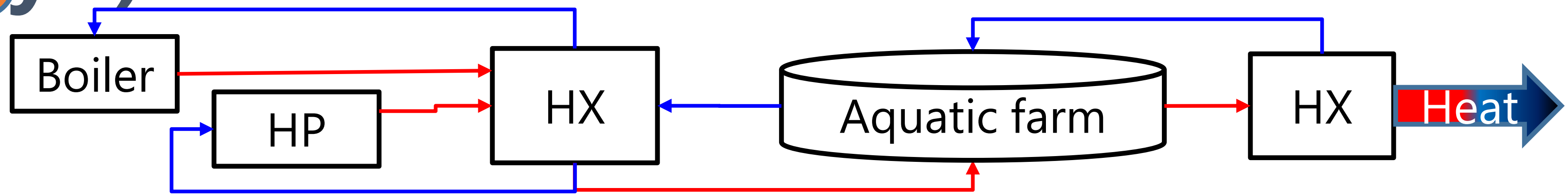


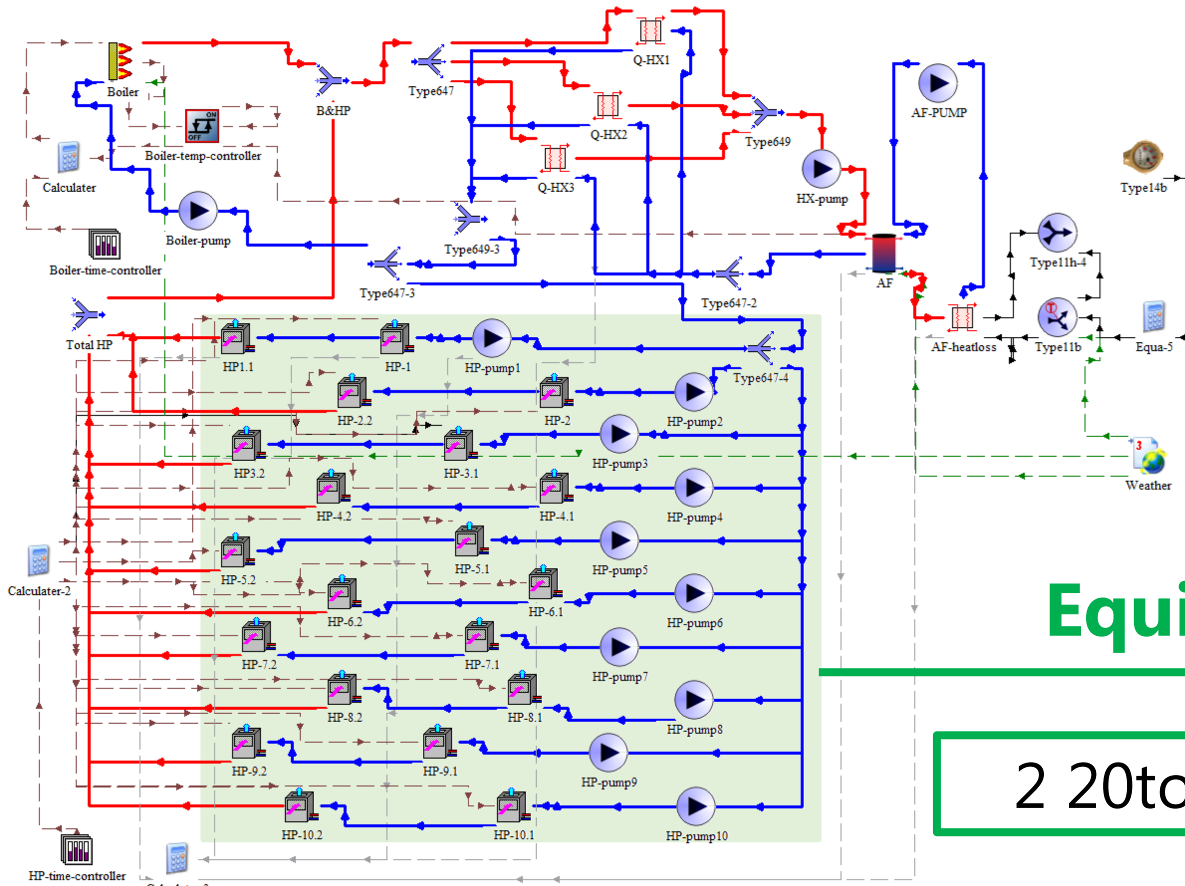
Heating system 1: Boiler heating system (290B-Sys.)



	Parameters	Unit	Value
Boiler  Type 695	Rated capacity	kW	290.7
	Pump	liter/hr.	6250
	Consumption power	kg/hr	3708
Boiler - Temperature controller  Type2-AquastatH	Set point temperature	ºC	25
	High limit monitoring temperature	ºC	70
	Turn on temperature difference	ºC	2
	Turn off temperature difference	ºC	0
HX  Type 5b	Overall heat transfer coefficient of exchanger	kJ/kg-K	280000
	Total load side flow rate	kg/s	25

Heating system 2: Heat pump and boiler heating system (HP-162B-Sys.)

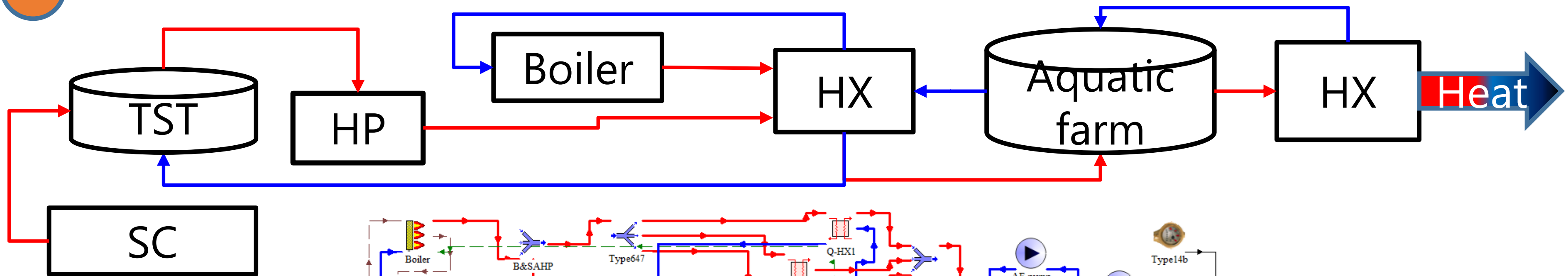


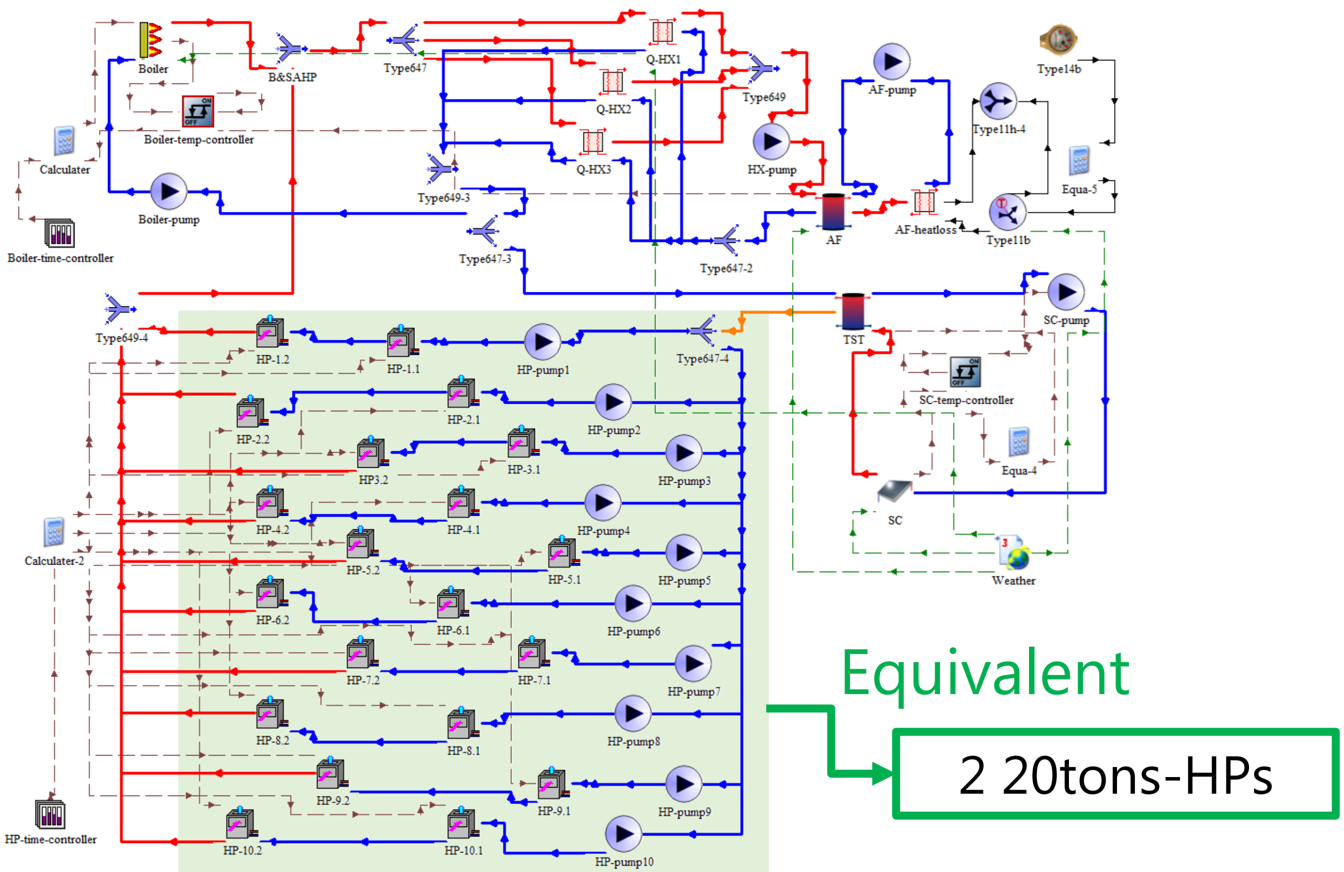


Equivalent

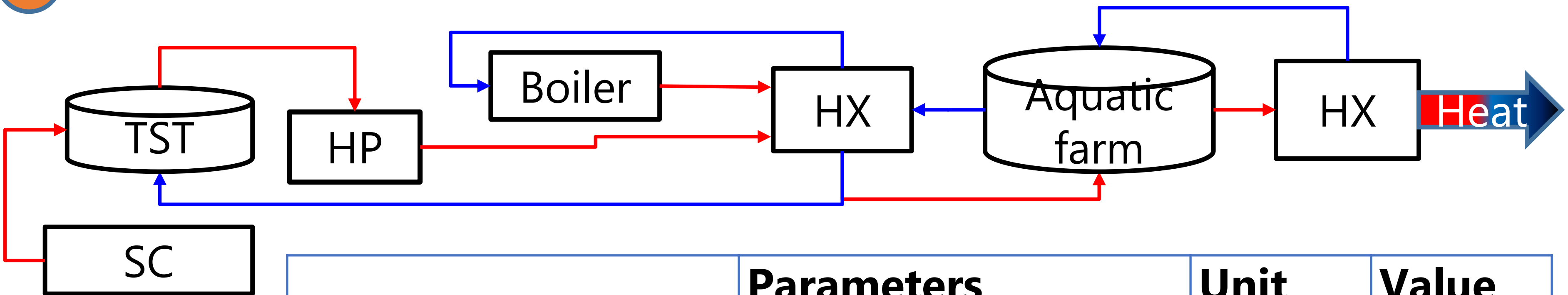
2 20tons-HPs

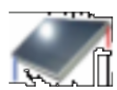
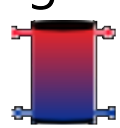
Heating system 3: Combination of SC-HP-162B-Sys. / SC-HP-37B-Sys.





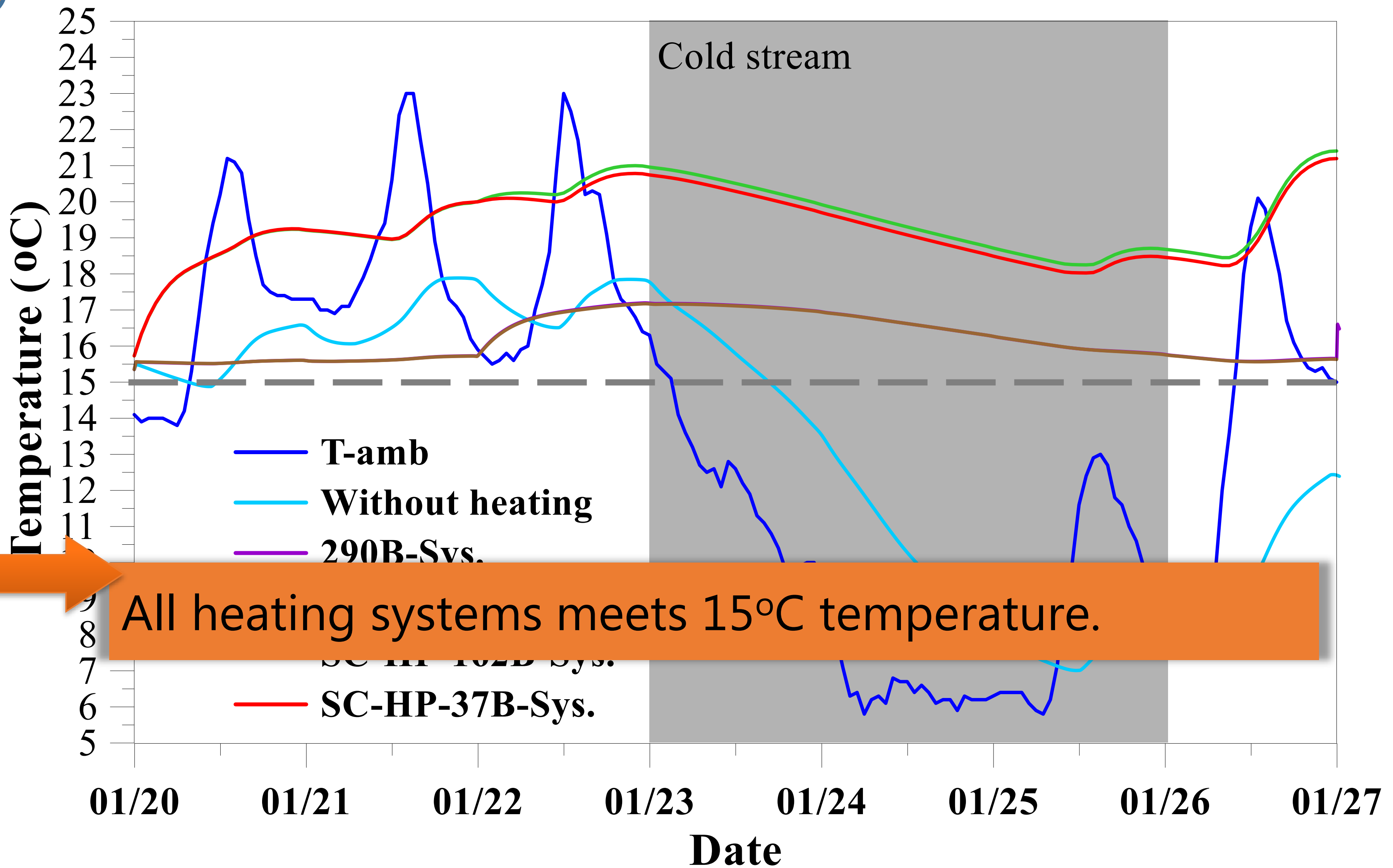
Heating system 3: Combination of SC-HP-162B-Sys. / SC-HP-37B-Sys.



	Parameters	Unit	Value
Solar collector (SC)  Type 1b	Number in series [20]	N/A	6
	Collector area	m^2	230.4
	Flow rate	kg/s	8
SC-temp difference controller  Type2b	Upper dead band dT	°C	7
	Lower dead band dT	°C	3
Thermal storage tank (TST)  Type 4a	Initial temperature	°C	24
	Tank volume	m^3	20
	Number of nodes	N/A	1
	Tank loss coefficient	W/m^2-K	3

[20] 李聰盛，郭明樺. 2017.

System comparisons – Aquatic farm temperature



All heating systems meets 15°C temperature.

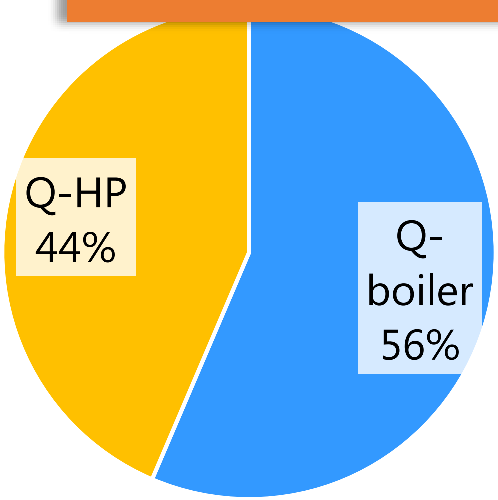
System comparisons – Proportion of heat source

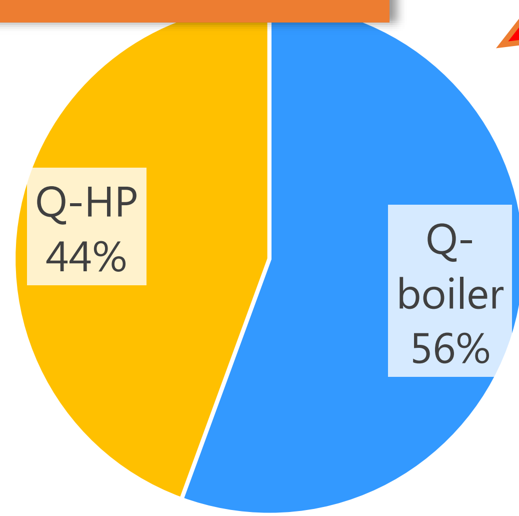
		290B-Sys.	HP-162B-Sys.	SC-HP-162B-Sys.	SC-HP-37B-Sys.
Total heat gain	(MJ)	1.250E+05	1.257E+05	1.276E+05	7.285E+04
Heat gain from different heating system					
Q_SC	%	0%	0%	1%	3%
Q_HP	%	0%	44%	43%	75%
Q_Boiler	%	100%	[illegible]	[illegible]	[illegible]

Boiler dominates

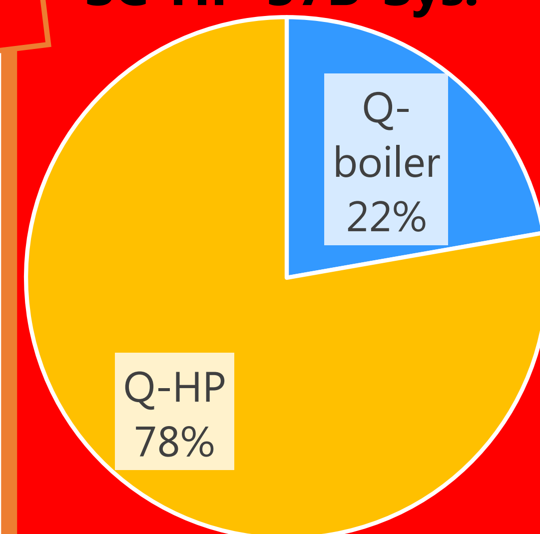
Renewable

...Sys.





SC-HP-37B-Sys.



System comparisons – Economy

- In usual, the aquatic farmer cultivates 2-3 seasons in one year. [21]

One hecture [21]	
Milkfishes	2.2×10^4 numbers
Shrimp	1.05×10^6 numbers

Cultivation cost [22]	
Milkfish	NTD 46.05/kg
Shrimp	NTD 17.87/kg

One adult	
Milkfish [23]	300g
Shrimp [24]	50g

0.125 ha

Milkfishes	Shrimp
2.8×10^3 numbers → NTD 3.8×10^4	1.3×10^5 numbers → NTD 1.2×10^5
Total NTD 1.5×10^5	

[21] 蘇甘棠. 2007
[22] 鄭嘉裕. 2009
[23] 维基百科编者. 虱目魚.
[24] http://fishdb.sinica.edu.tw/chi/importpic_2013.php?id=32.

System comparisons – Economy

- Assume
  1. NTD 155.263 k per season
  2. One cold stream per year

- Cost recovering time (unit: year) $= \dfrac{\text{the total cost}}{\text{the loss of one year}}$
- Total cost = investment cost + operating cost

		290B-Sys.	HP-162B-Sys.	SC-HP-162B-Sys.	SC-HP-37B-Sys.
Total cost	(NTD)	545.326 k	699.966 k	2385.453 k	2193.981 k
Payback period	(year)	4	5	15	14

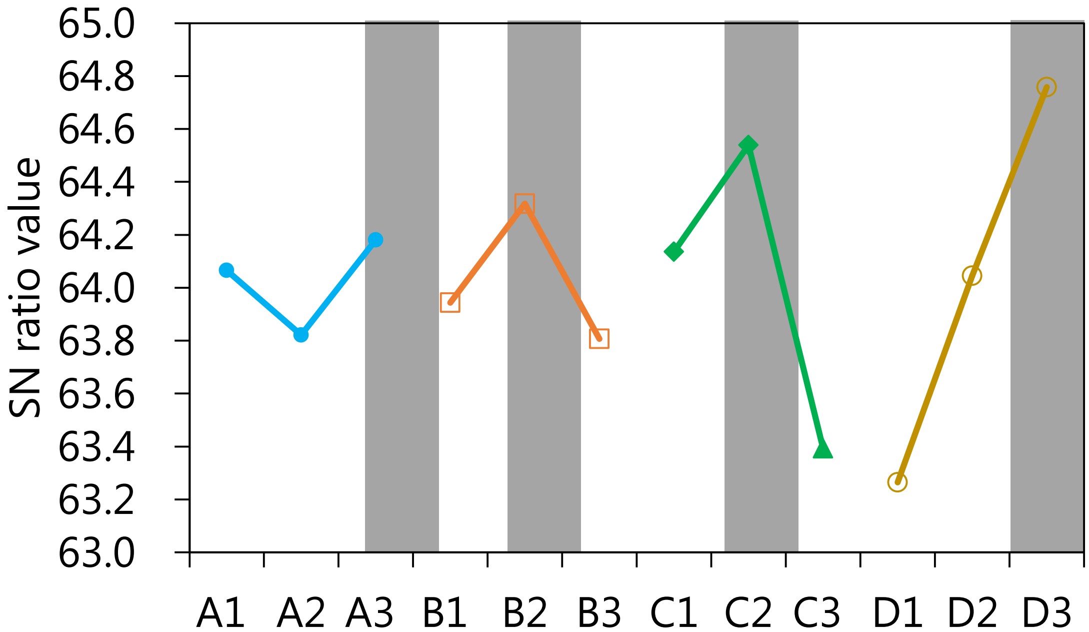
System comparisons – environmental impact

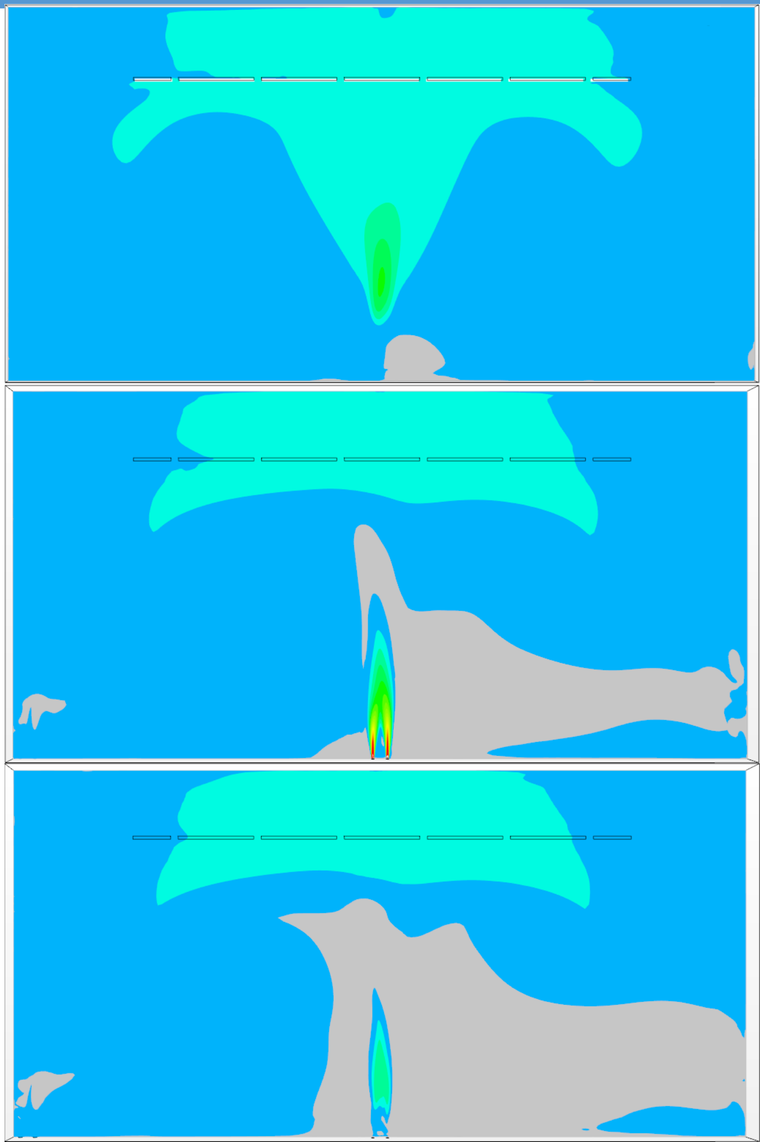
		290B-Sys.	HP-162B-Sys.	SC-HP-162B-Sys.	SC-HP-37B-Sys.
Heat gain from Boiler	(MJ)	1.250E+05	7.092E+04	7.092E+04	1.620E+04
Consumption of diesel oil	(Liter)	3556.95	2005.81	2005.81	458.33
CO_2 emission from diesel oil [25]	(kg)	9390.36	5295.33	5295.33	1209.99
Payback period	(year)	4	5	15	14
CO_2 emission from diesel oil during payback period	(kg)	32981.52	23872.72	81357.15	17098.04

[63] http://ecoscore.be/en/info/ecoscore/co2.

Conclusions – Aquatic farm geometry

- Aquatic farm optimization





A3: Two inlets of the height at 1.5 m
B2: inlets and outlets at same side
C2: Barrier length at 30 m
D3: Barrier distance from inlet wall at 20 m

Conclusions – Heating systems

■ Comparison the heating system

	Most	Least
Investment cost	SC-HP-162B-Sys.	290B-Sys.
Cost recovering time	SC-HP-162B-Sys.	290B-Sys.
CO_2 emission per year	290B-Sys	SC-HP-37B-Sys.
CO_2 emission from diesel oil during payback period	SC-HP-37B-Sys.	SC-HP-37B-Sys.

✓ Suitable for the optimized aquatic farm **during the cold stream**

→ **HP & boiler heating system**

Thank you for your attention

Thank you for your attention

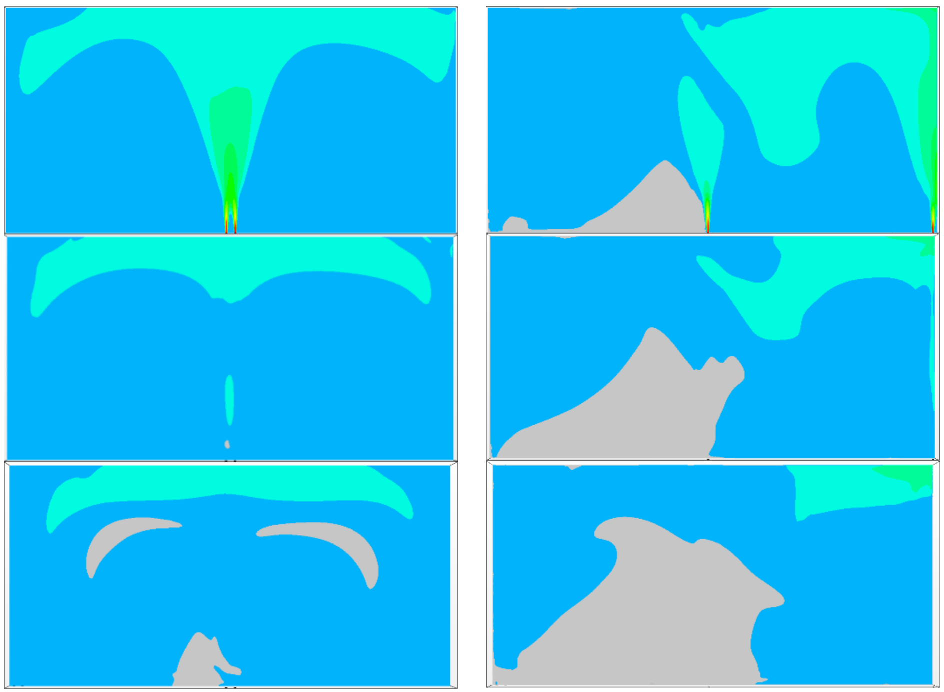
1. Distance between inlet 1 & inlet2

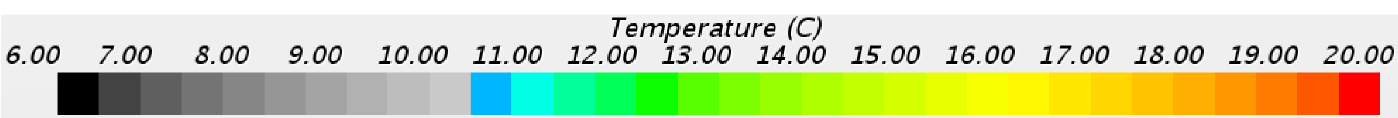
1-1   1-2

y=-0.5m

y=-1.1m

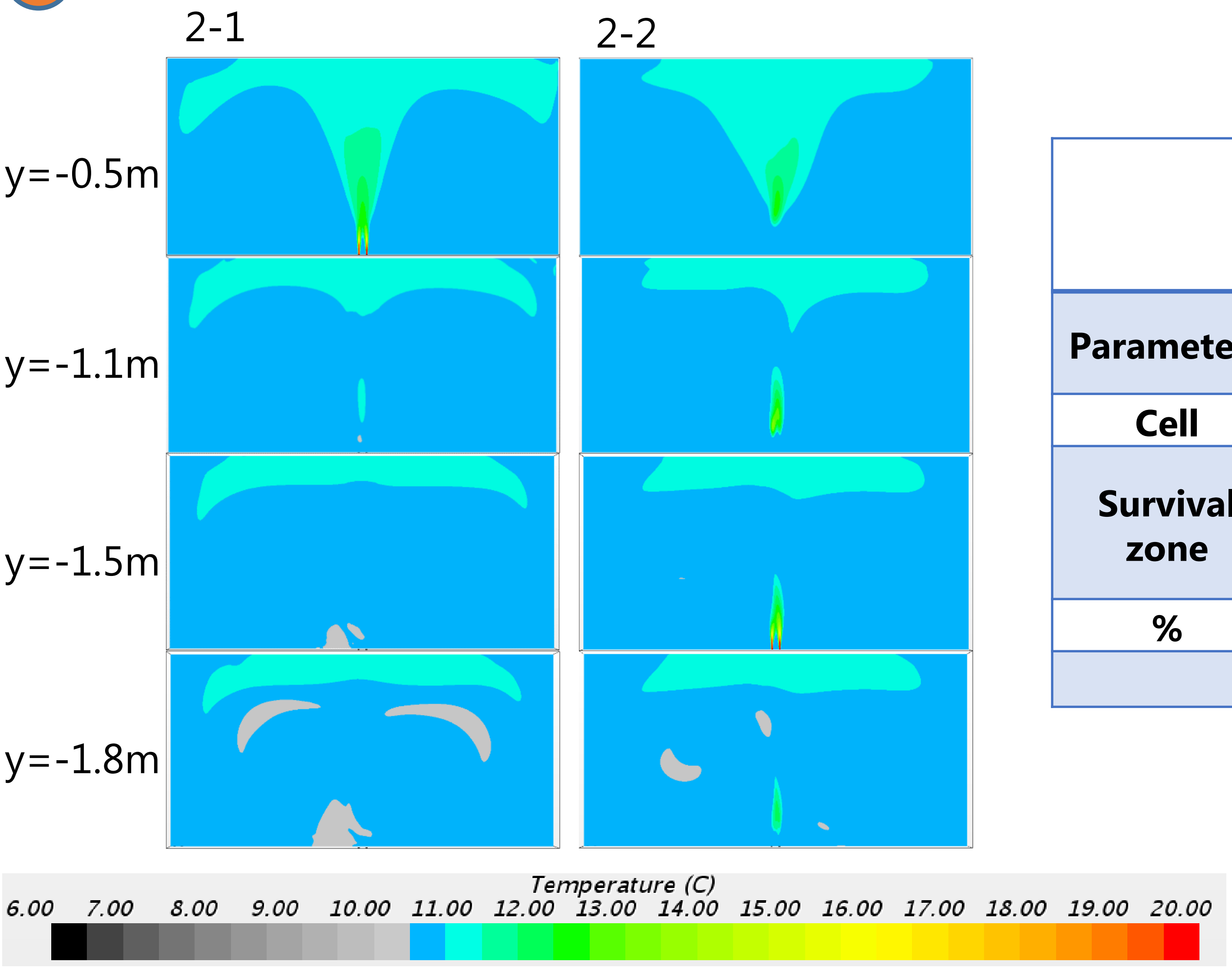
y=-1.8m





Position Inlet2 as fixed inlet1		
	1-1	1-2
Parameters	Inlet2 =0.5	Inlet2 =12.5
Cell	2878154	2458295
Survival zone	1936.18	1707.12
%	77.73%	68.53%
	9.20%	

2. Two inlets of the height



	2-1	2-2
Parameters	-0.5	-1.5
Cell	2878154	2938489
Survival zone	1936.18	2133.86
%	0.7773	0.8566
	0.0794	

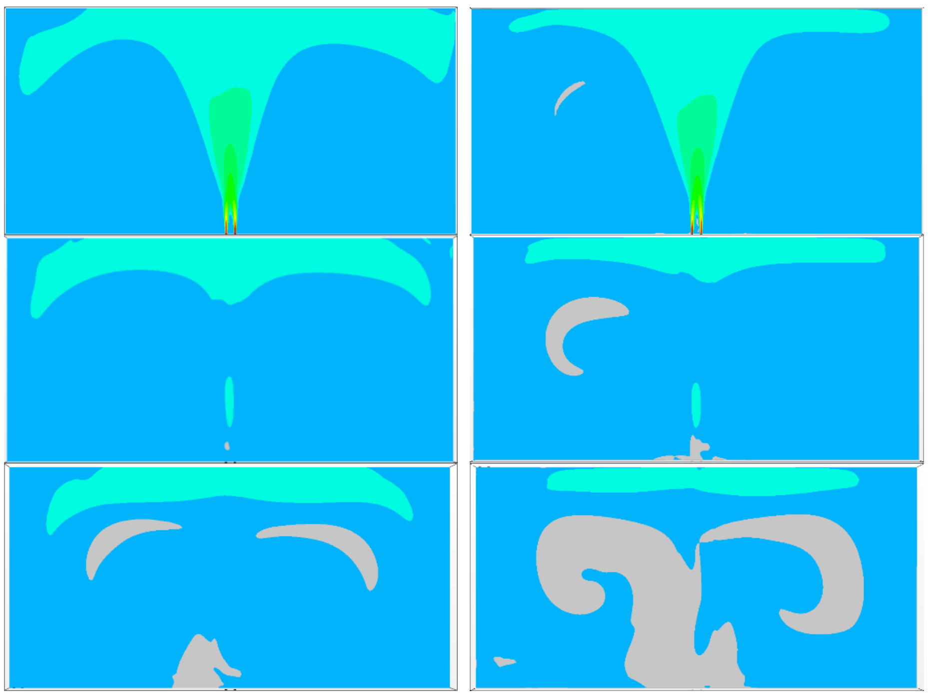
3. Outlets positions

3-1 3-2

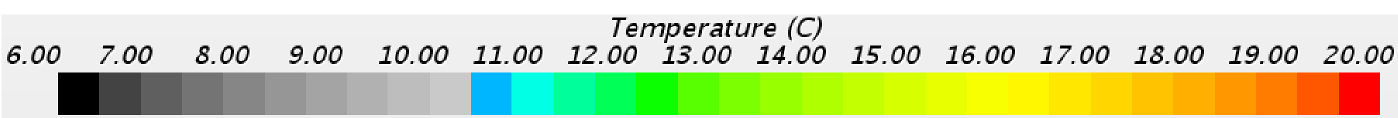
y=-0.5m

y=-1.1m

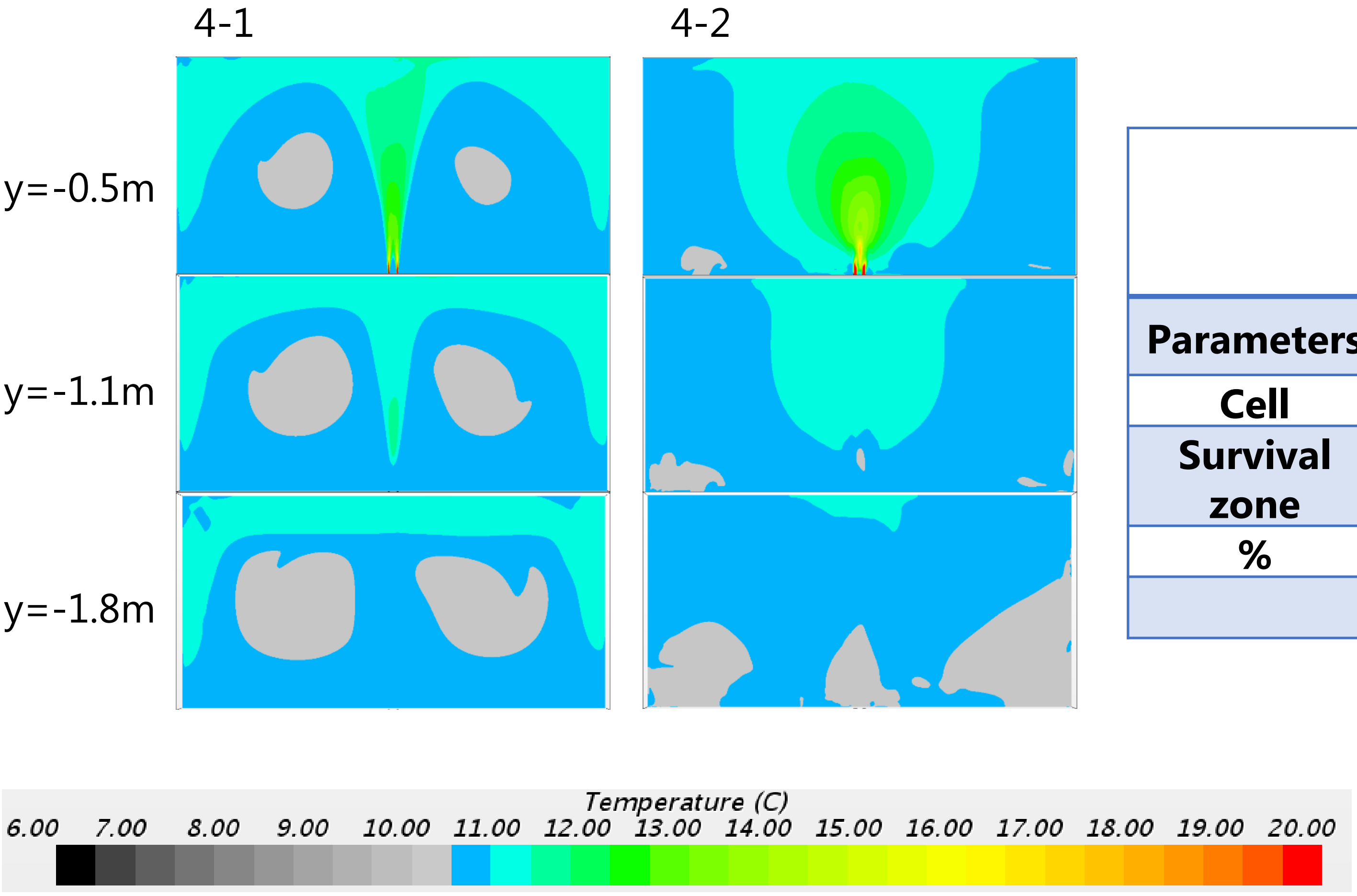
y=-1.8m



	3-1	3-2
Parameters	Same side	Opposite side
Cell	2878154	2610467
Survival zone	1936.18	1622.3
%	77.73%	65.13%
	12.60%	

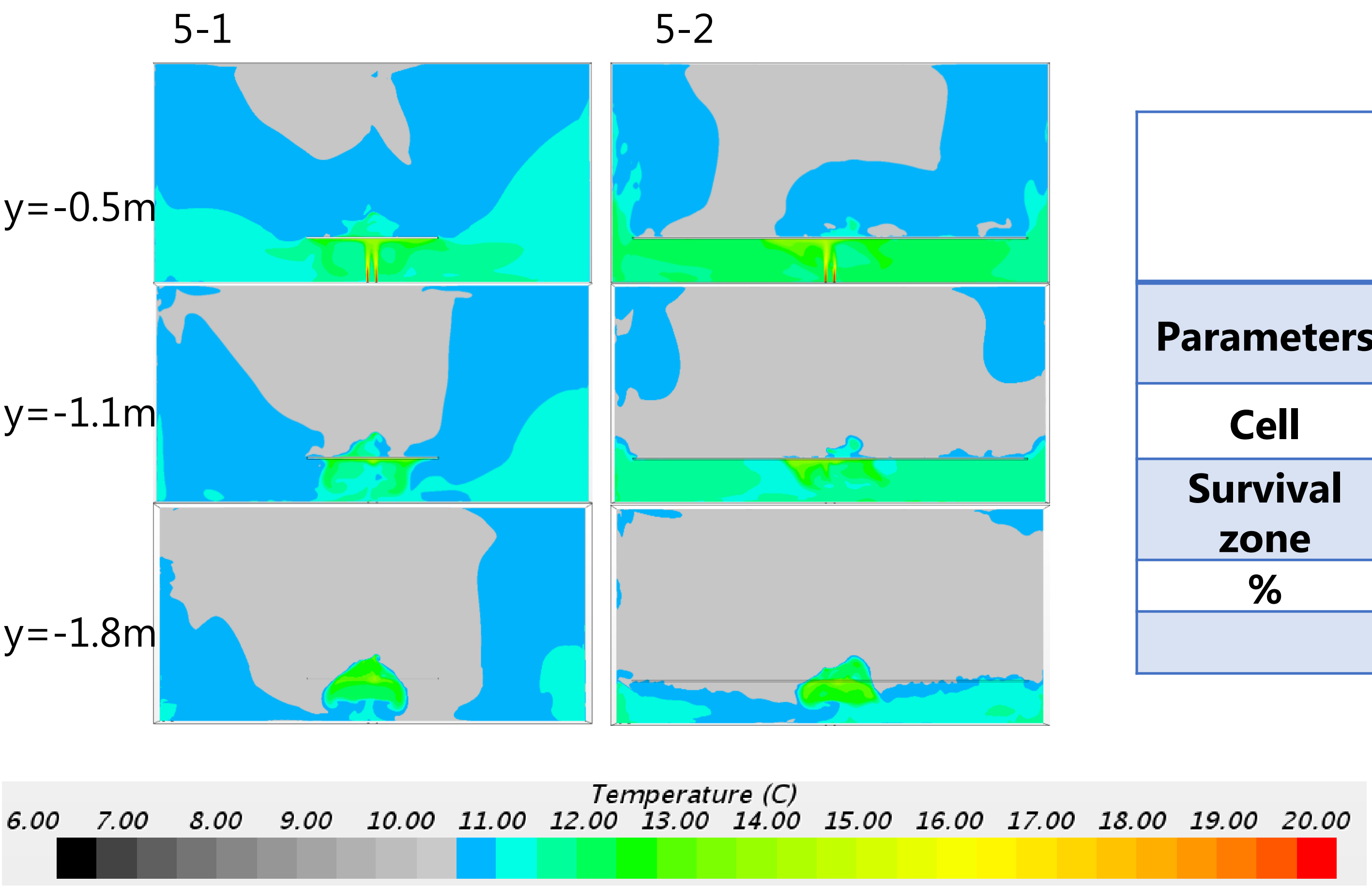


4. Velocity (fixed mass flowrate)



	4-1	4-2
Parameters	V1	V2
Cell	2913113	3060811
Survival zone	1709.8	1611.61
%	68.64%	64.70%
	3.94%	

5. Barrier length



	5-1	5-2
Parameters	Length =15m	Length =45m
Cell	2995764	2610467
Survival zone	1273.12	811.85
%	51.03%	32.65%
	18.38%	

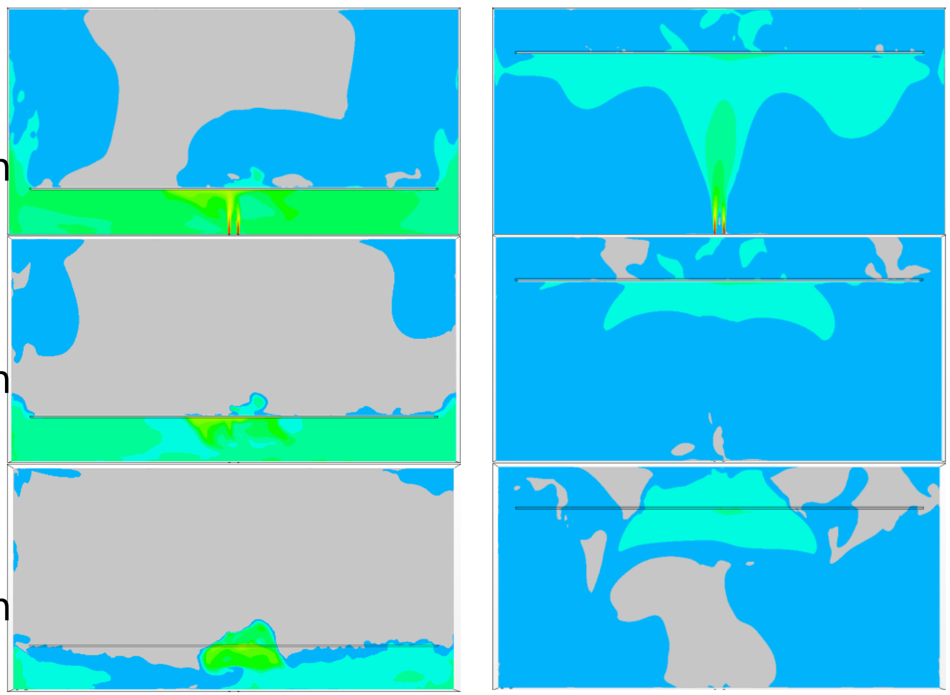
6. Barrier position

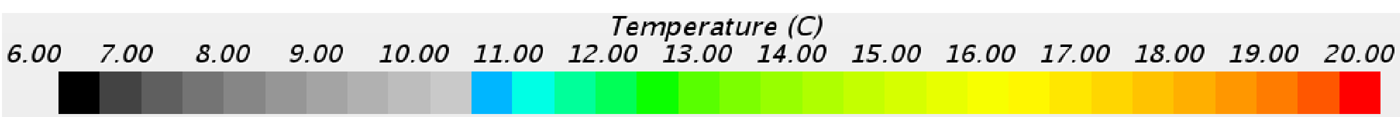
6-1 6-2

y=-0.5m

y=-1.1m

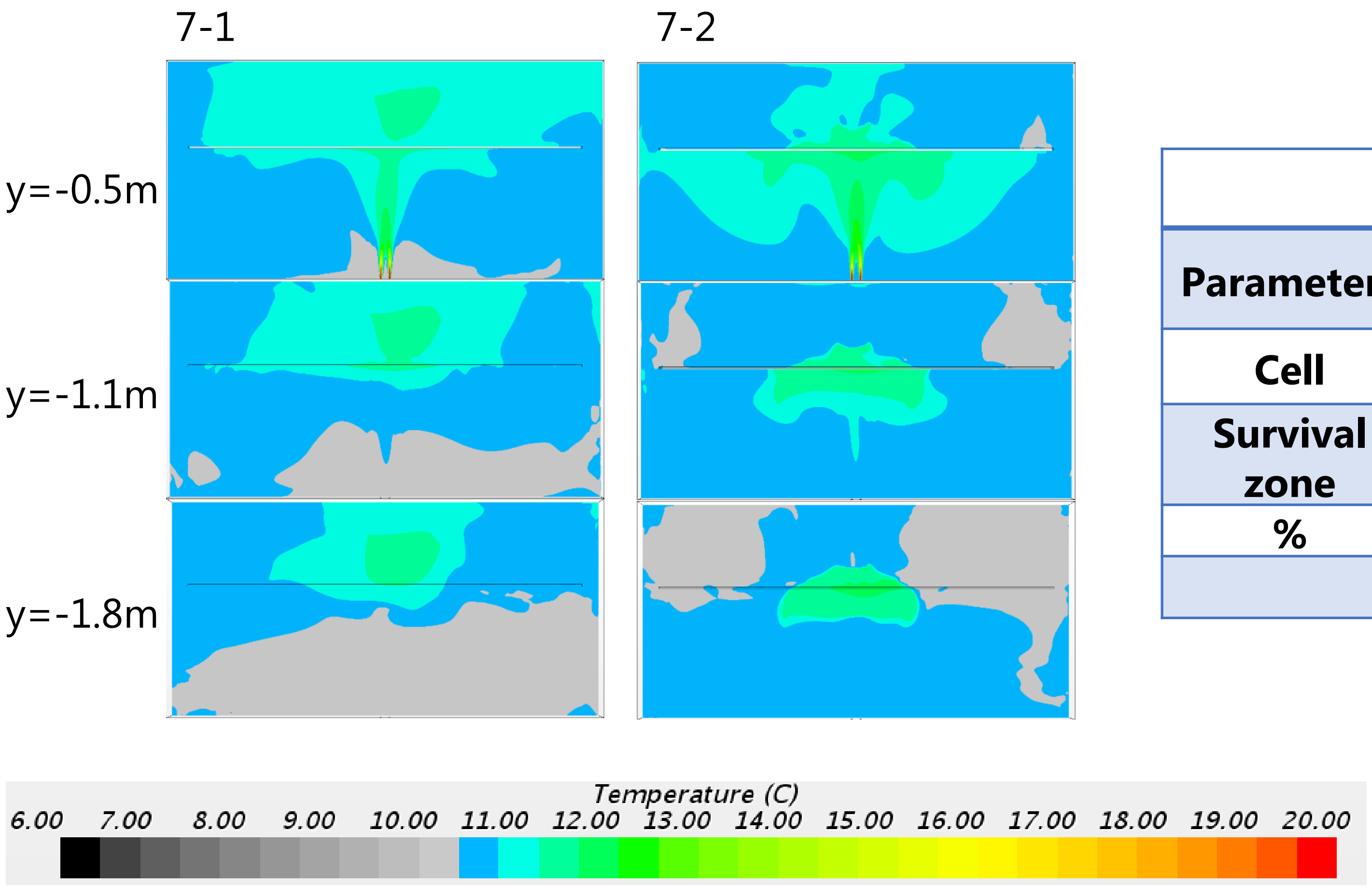
y=-1.8m





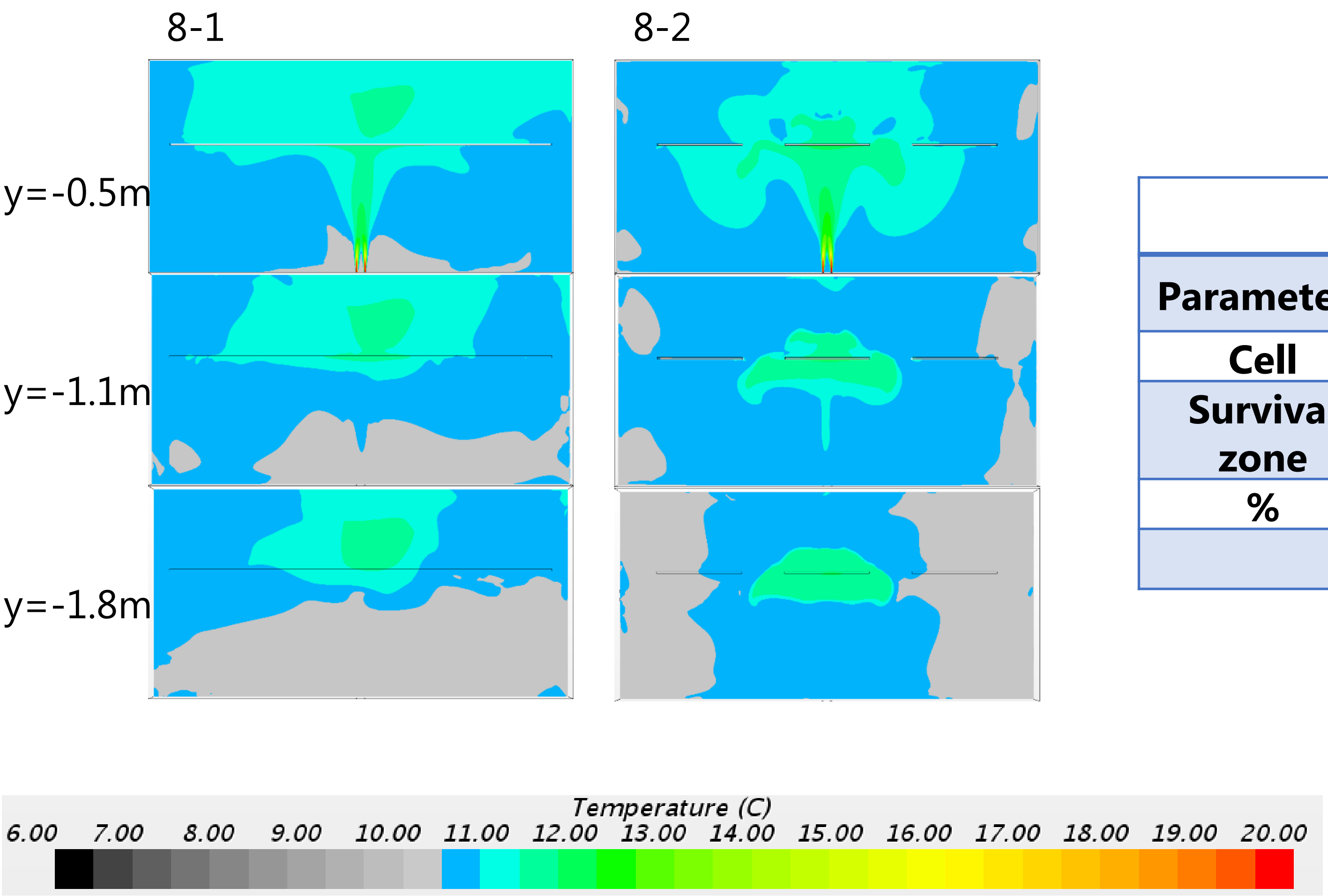
	6-1	**6-2**
Parameters	Distance =10m	Distance =20m
Cell	2622267	2613223
Survival zone	1264.8	1625.18
%	50.77%	65.24%
	14.47%	

7. Barrier thickness



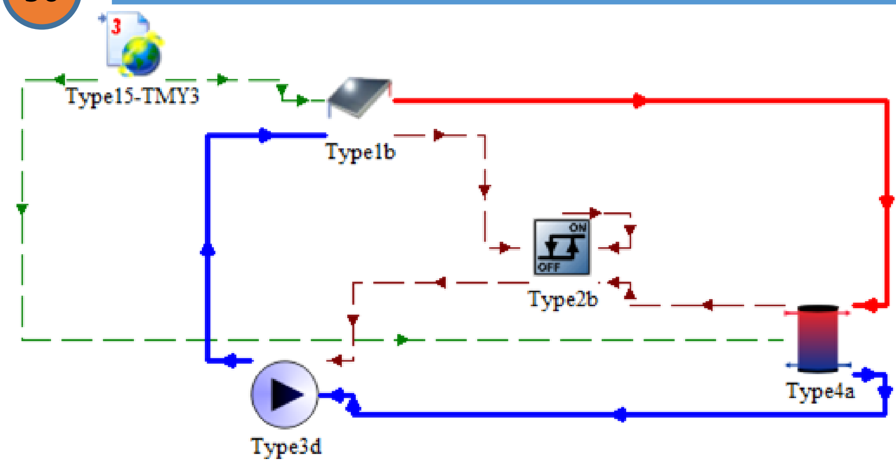
	7-1	7-2
Parameters	Depth =0.75m	Depth =1.5m
Cell	2632526	2568469
Survival zone	1671.17	1682.76
%	67.09%	67.55%
	0.47%	

8. Barrier numbers

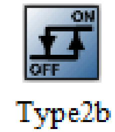


	8-1	8-2
Parameters	1*30	10*3
Cell	2767419	2817395
Survival zone	1518.4	1494.07
%	60.96%	59.98%
	0.98%	

System Diagram (1)

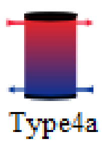


Controller



Parameter	Value	Unit
Upper dead band ΔT	7	℃
Lower dead band ΔT	3	℃

Storage tank



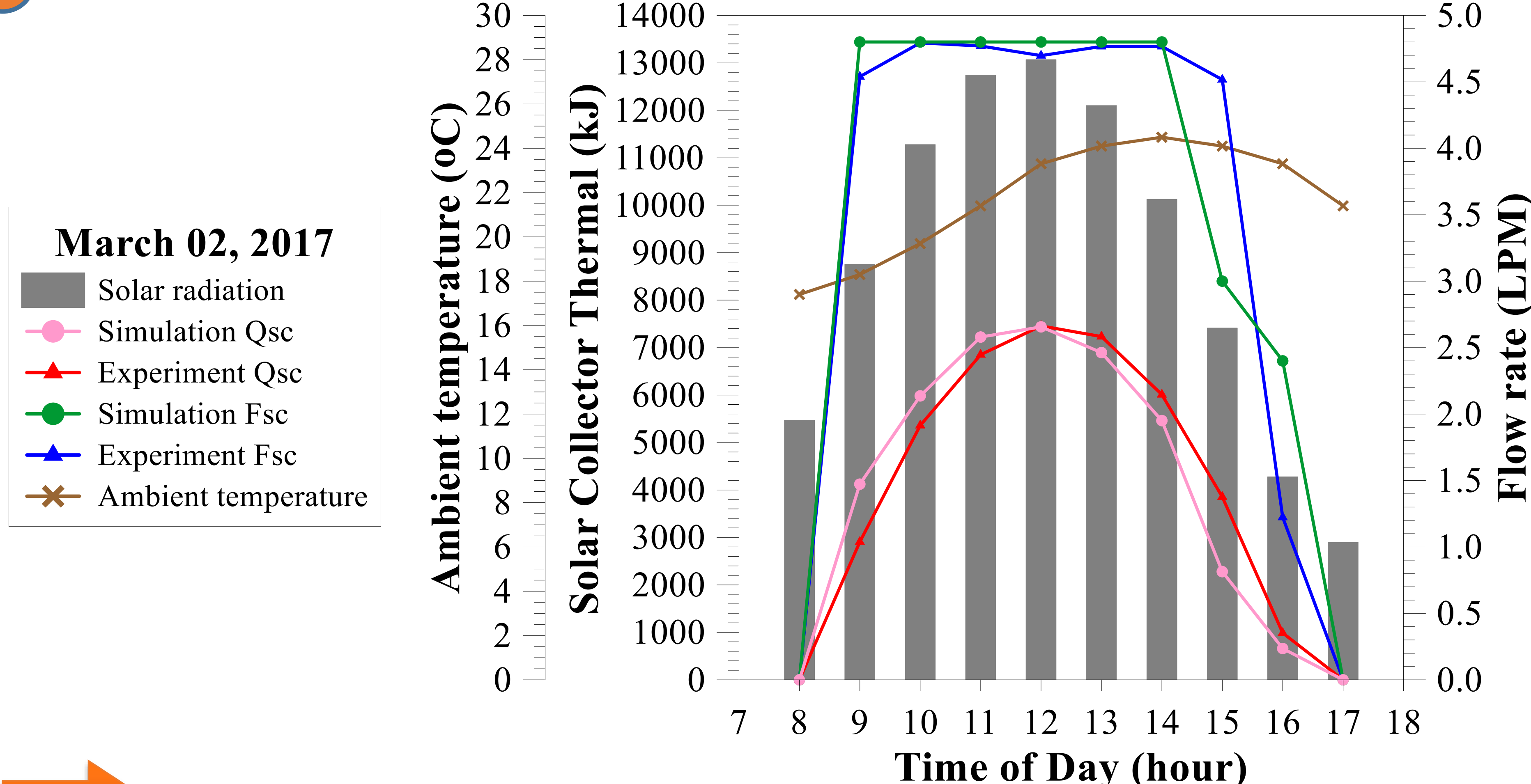
Parameter	Value	Unit
Cold side temperature	25	℃
Initial nodal temperature	25	℃
Tank volume	460	L
Number of nodes	3	N/A

Pump

Parameter	Value	Unit
Maximum flow rate	4.8	L/min
Maximum power	0.37	kW

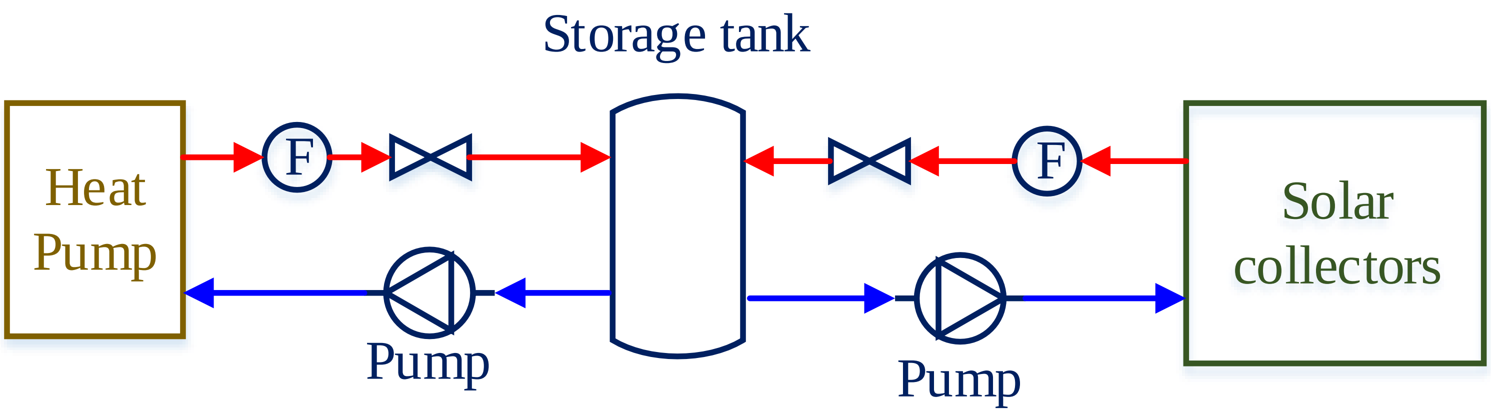
Validated system (1) - Solar Water Heating System

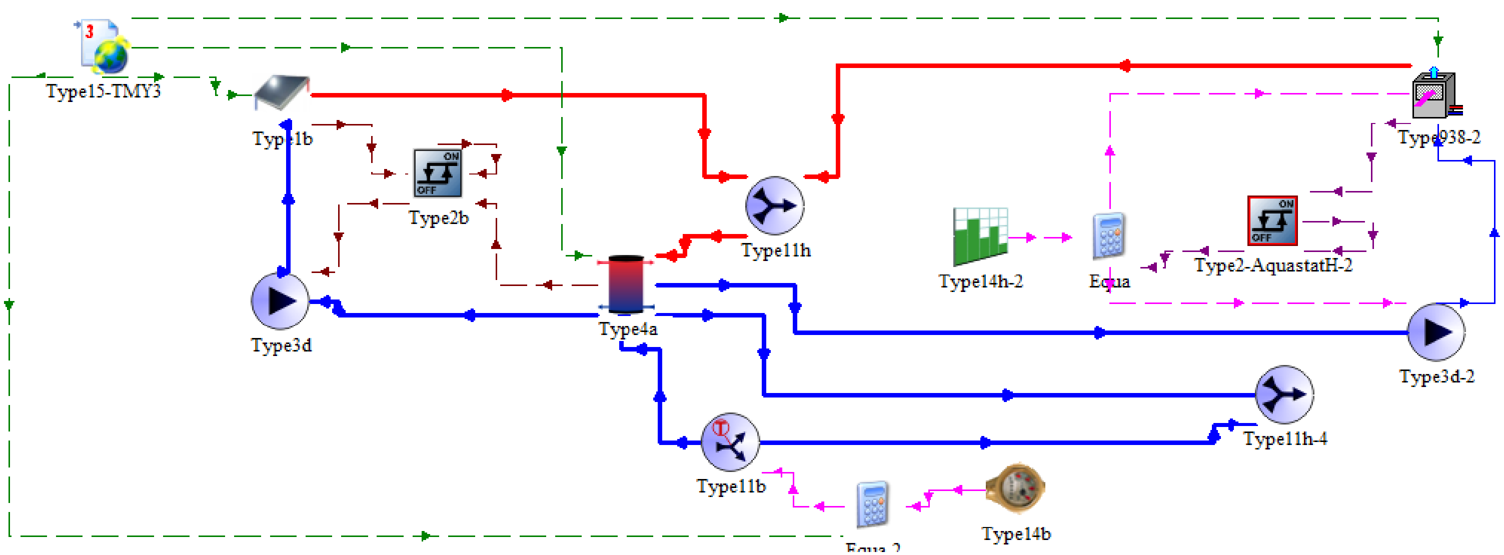
57



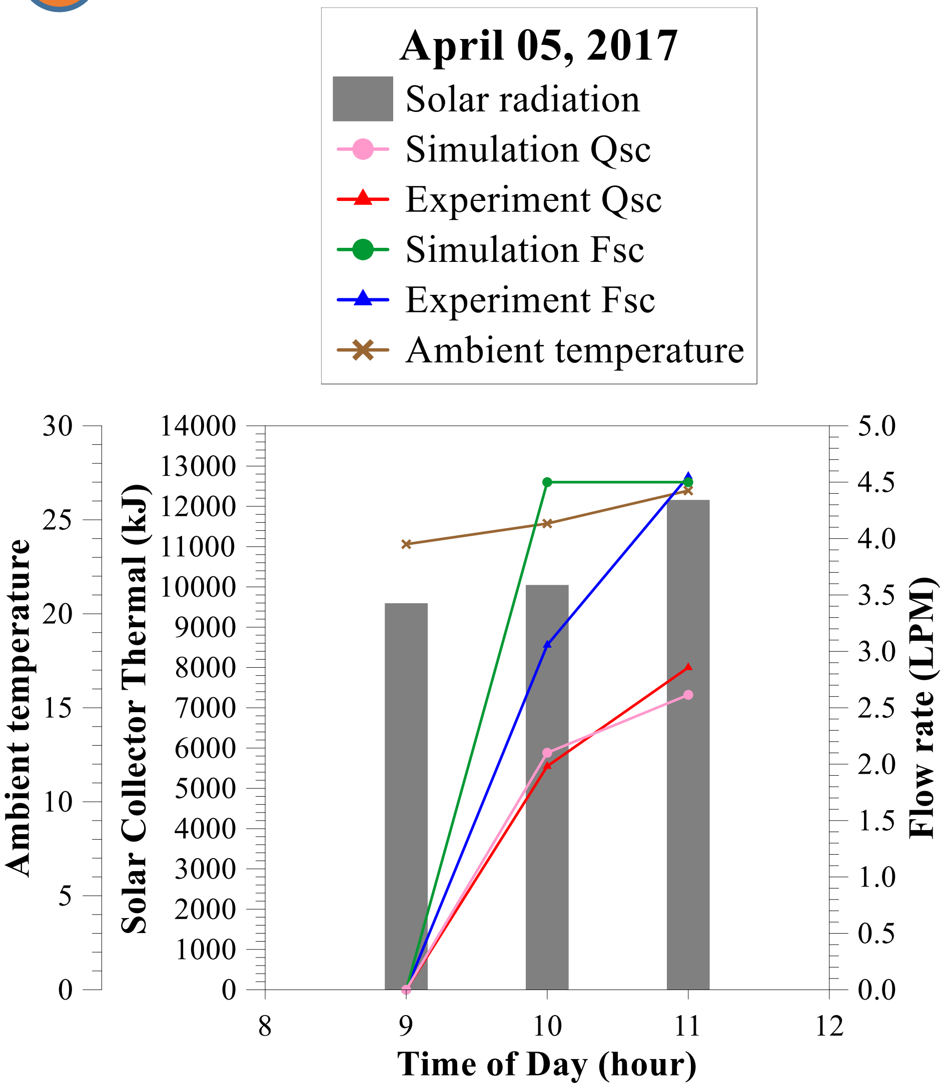
Validate parameters of solar thermal

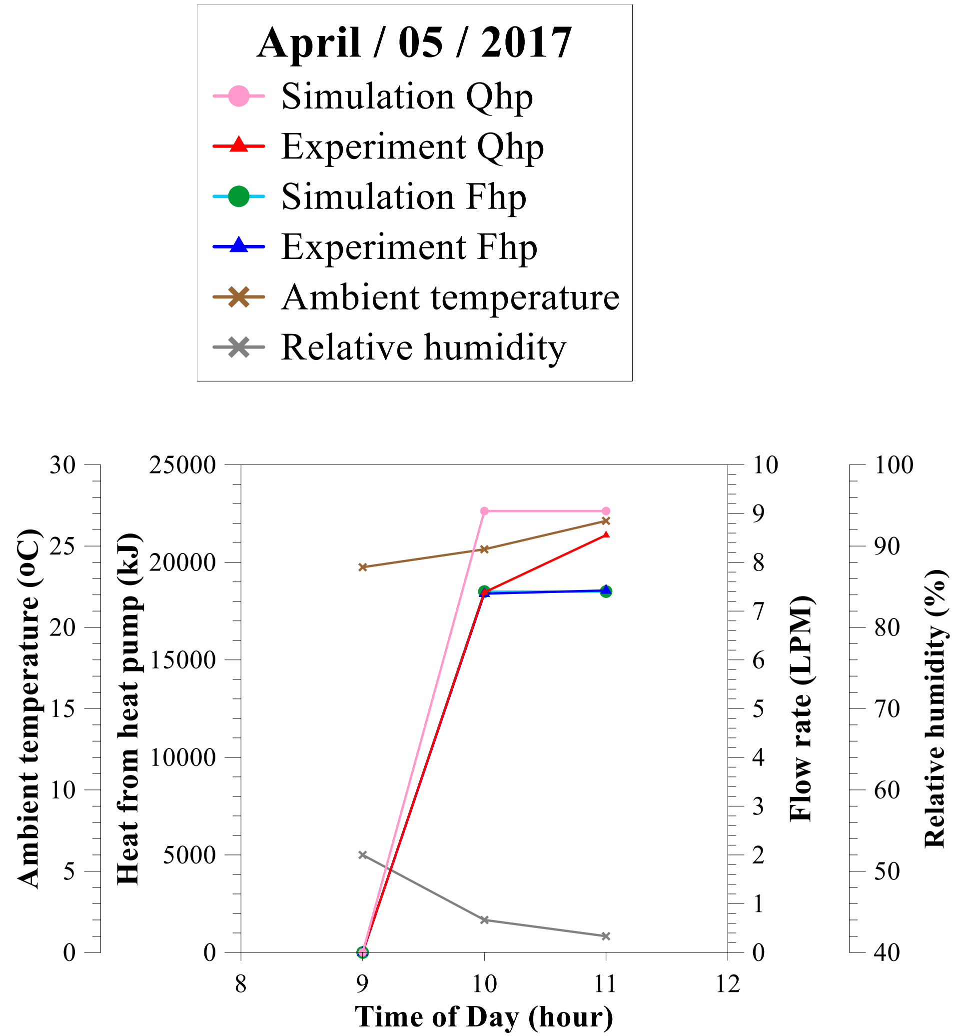
System Diagram (3)





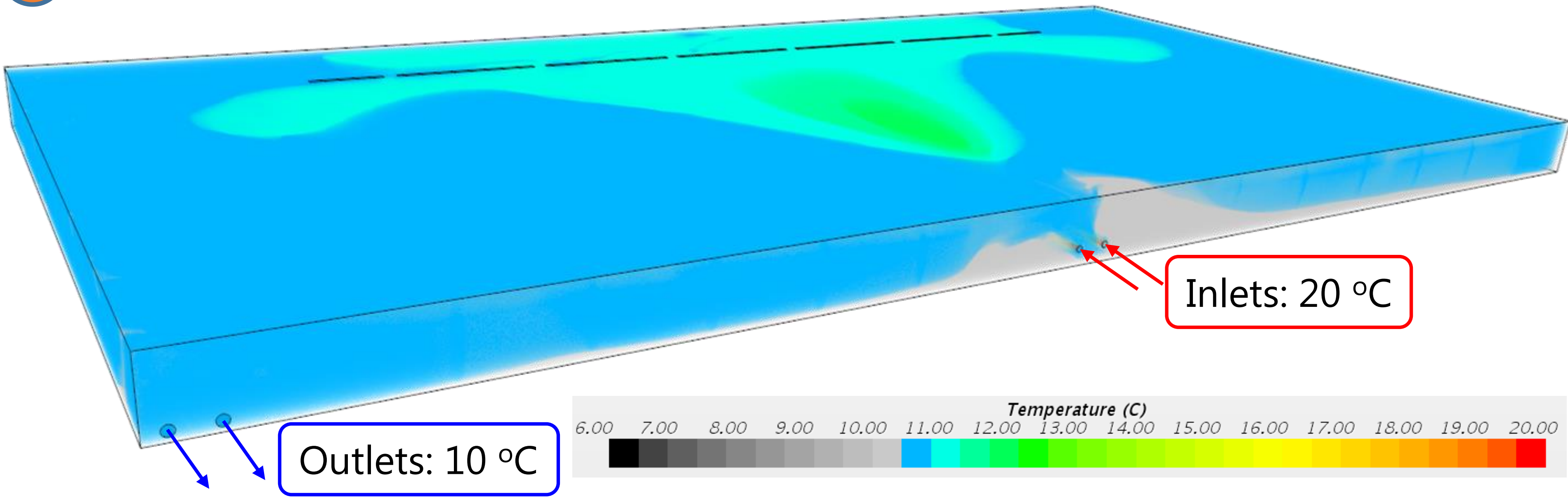
Validated system (3)

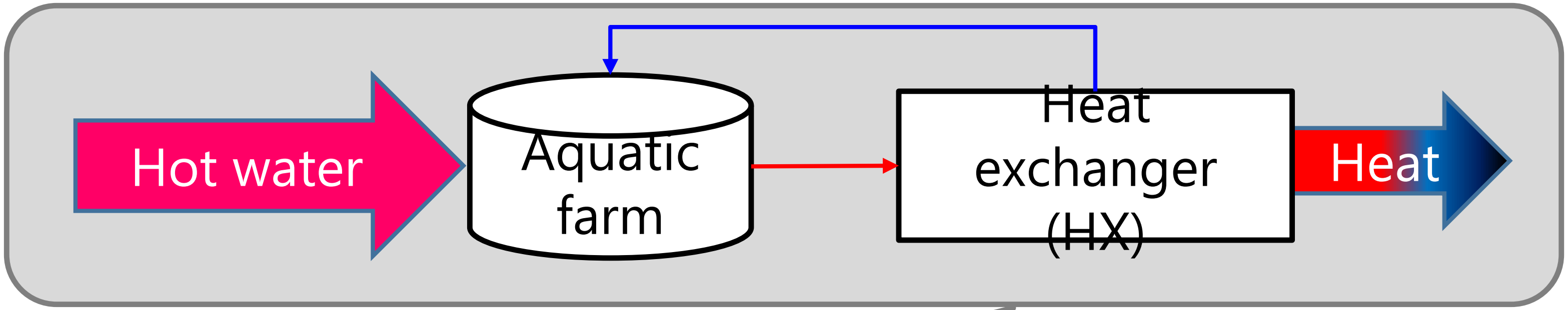




Relationship between TRNSYS and STAR-CCM+

60

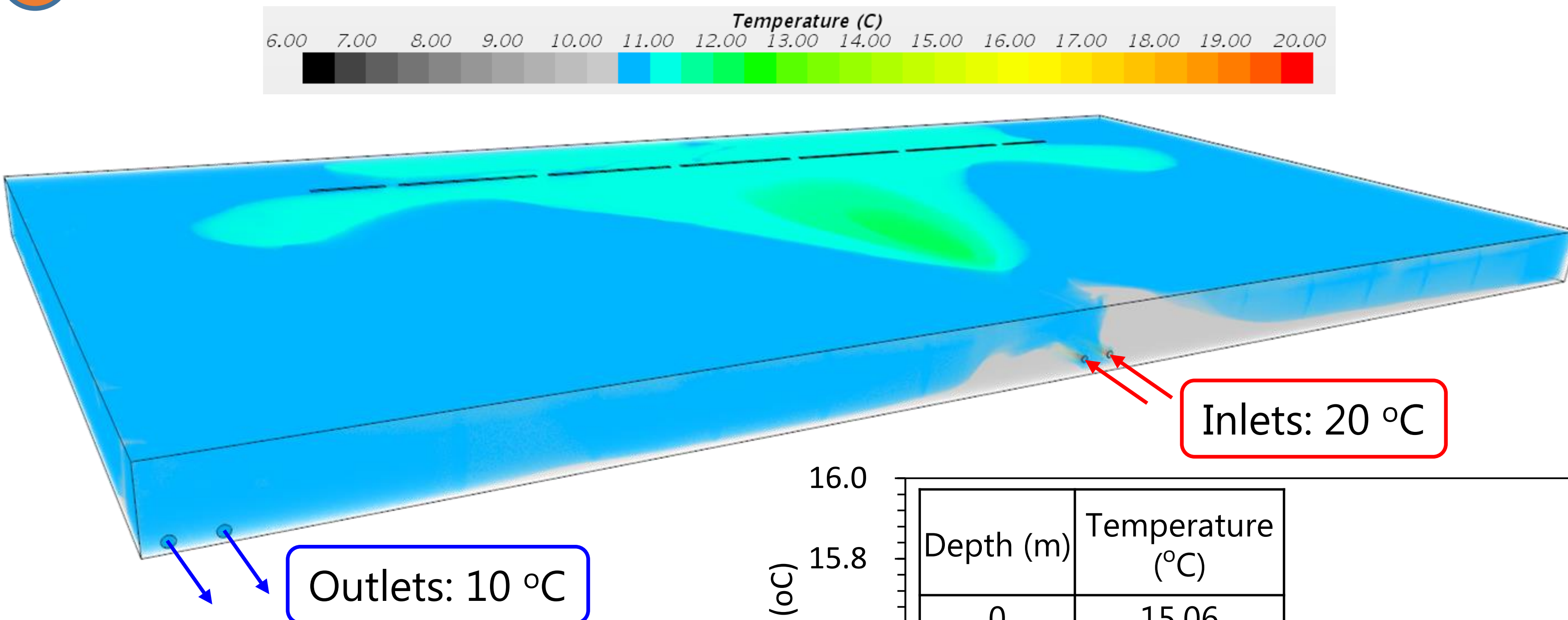


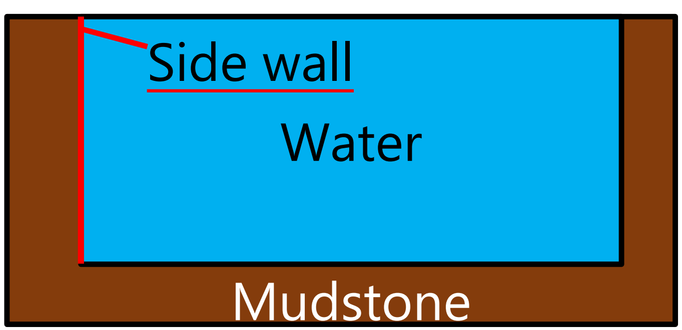


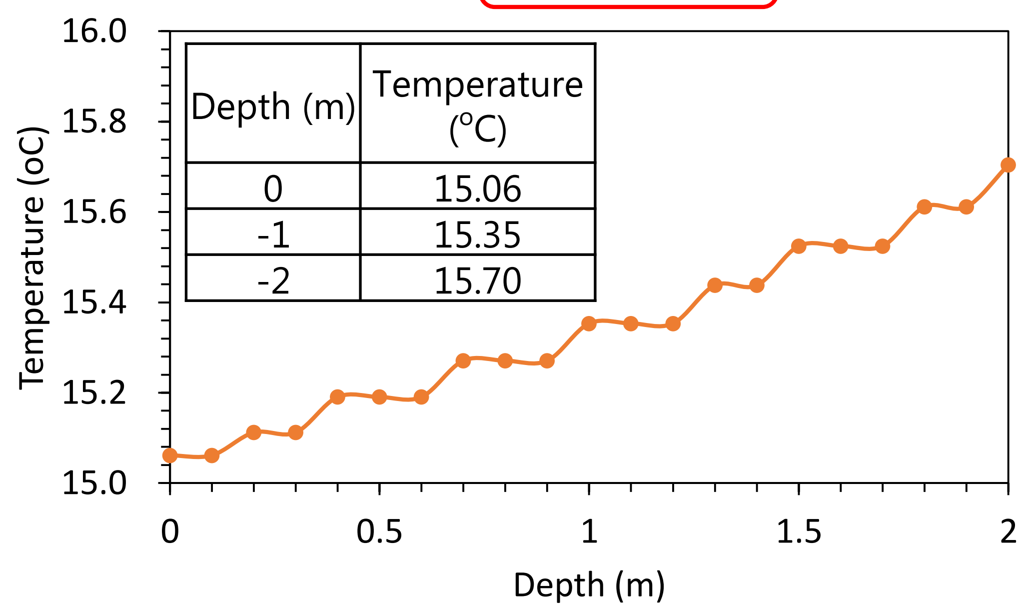
Imitate heat loss via HX

Relationship between TRNSYS and STAR-CCM+

61

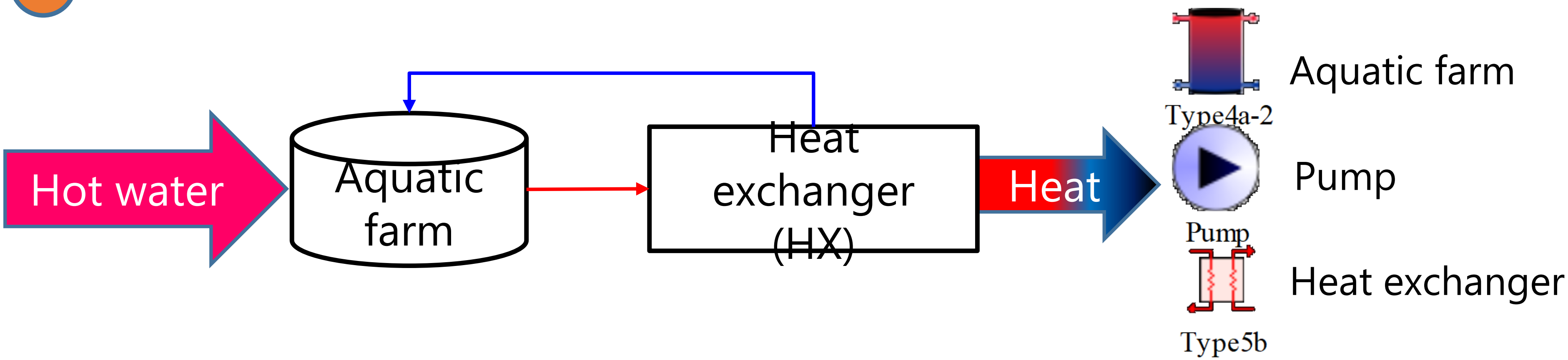


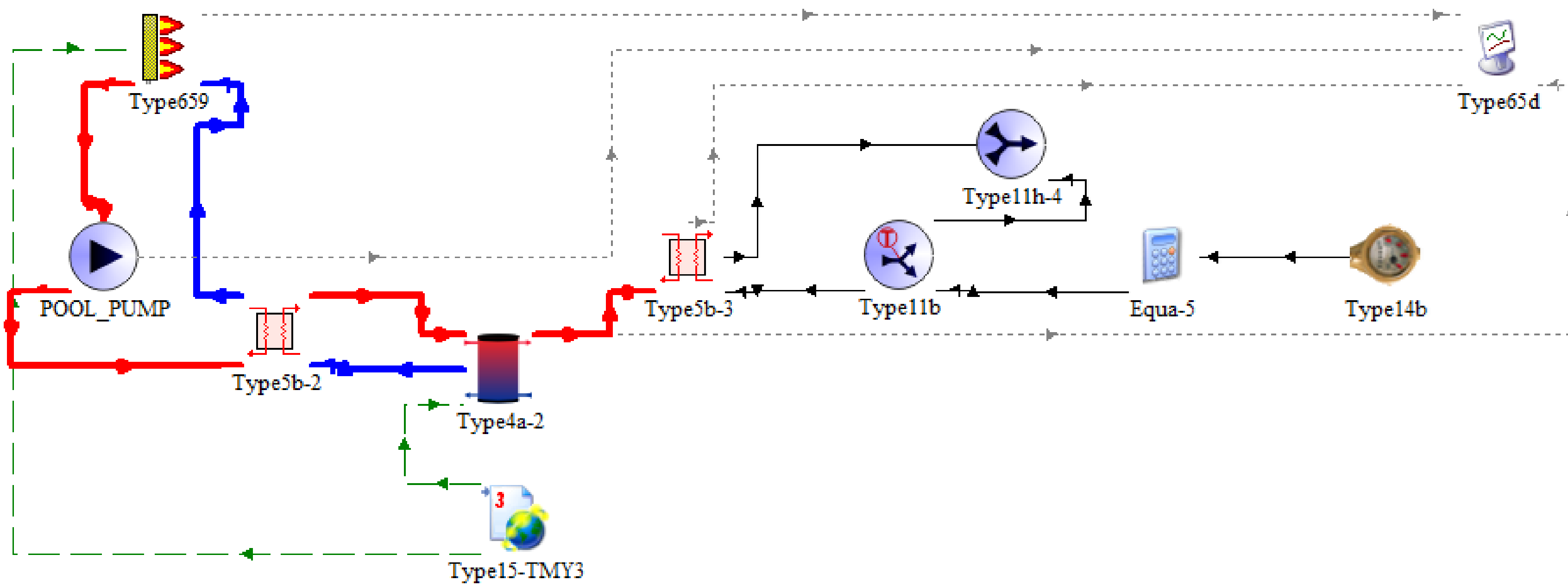




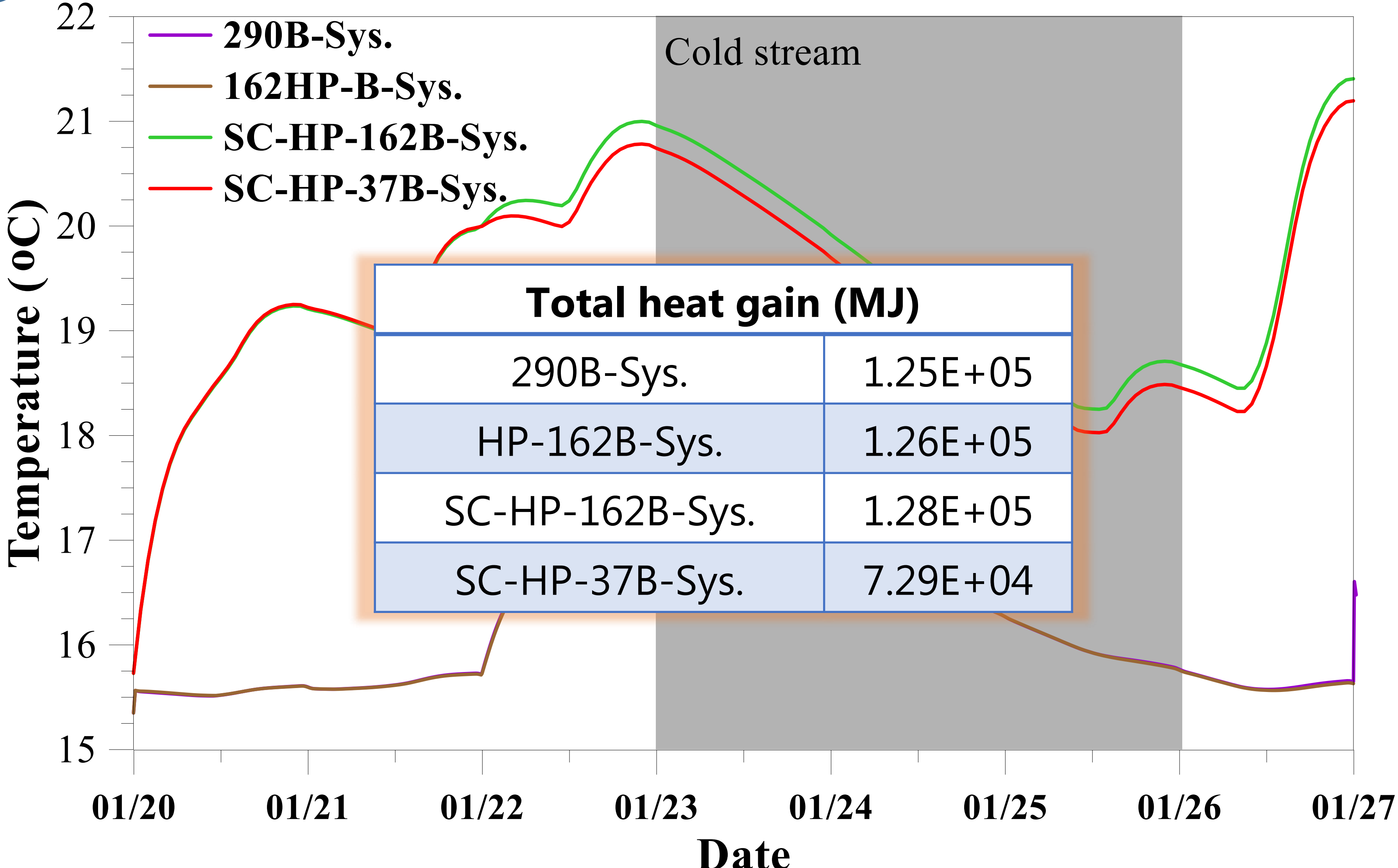
Depth (m)	Temperature (°C)
0	15.06
-1	15.35
-2	15.70

Relationship between TRNSYS and STAR-CCM+

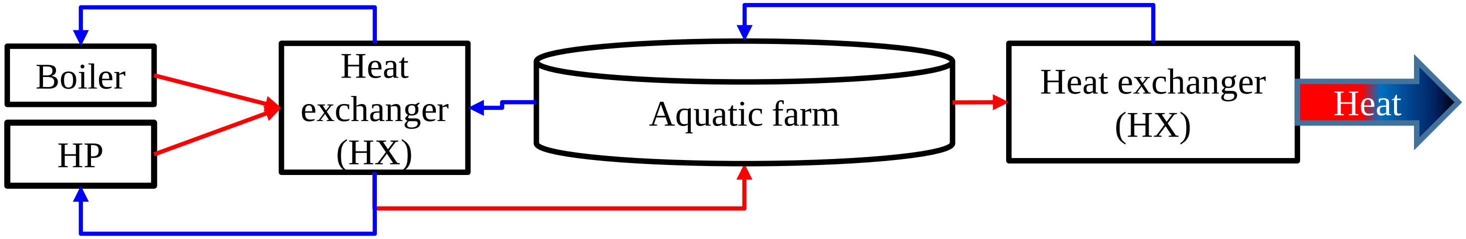


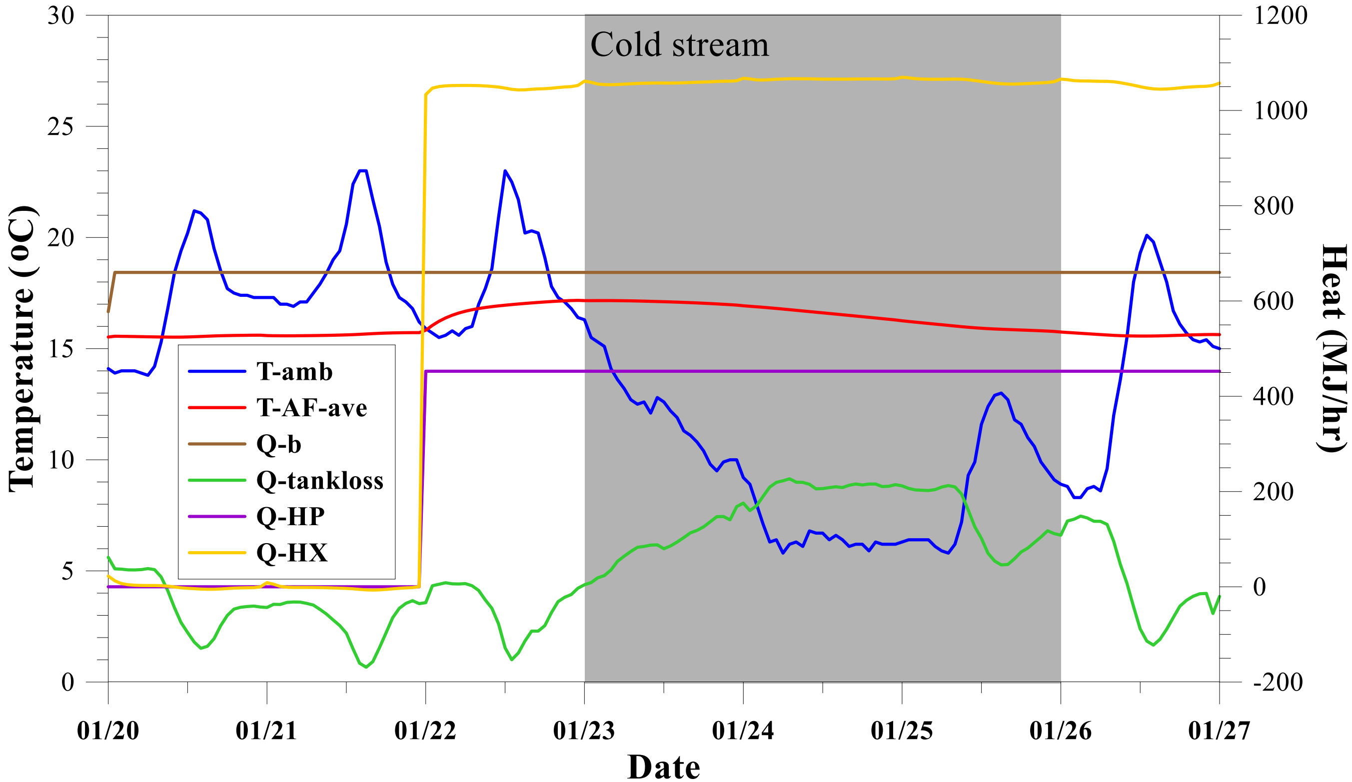


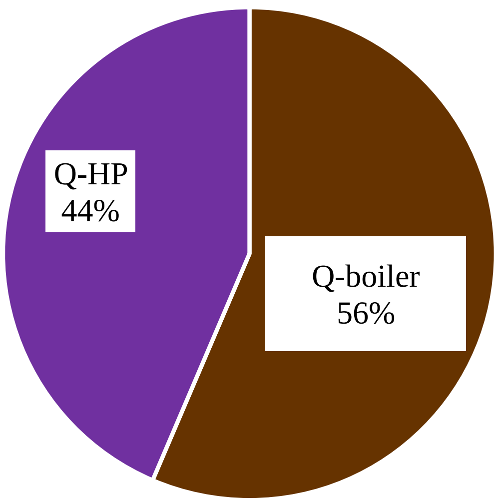
System comparisons – Aquatic farm temperature

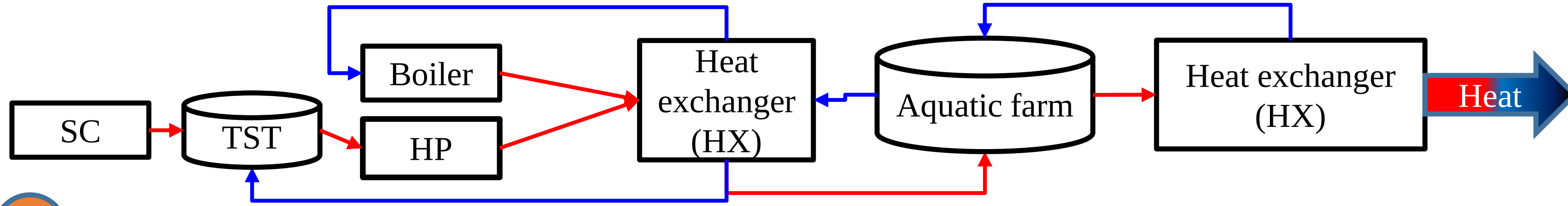


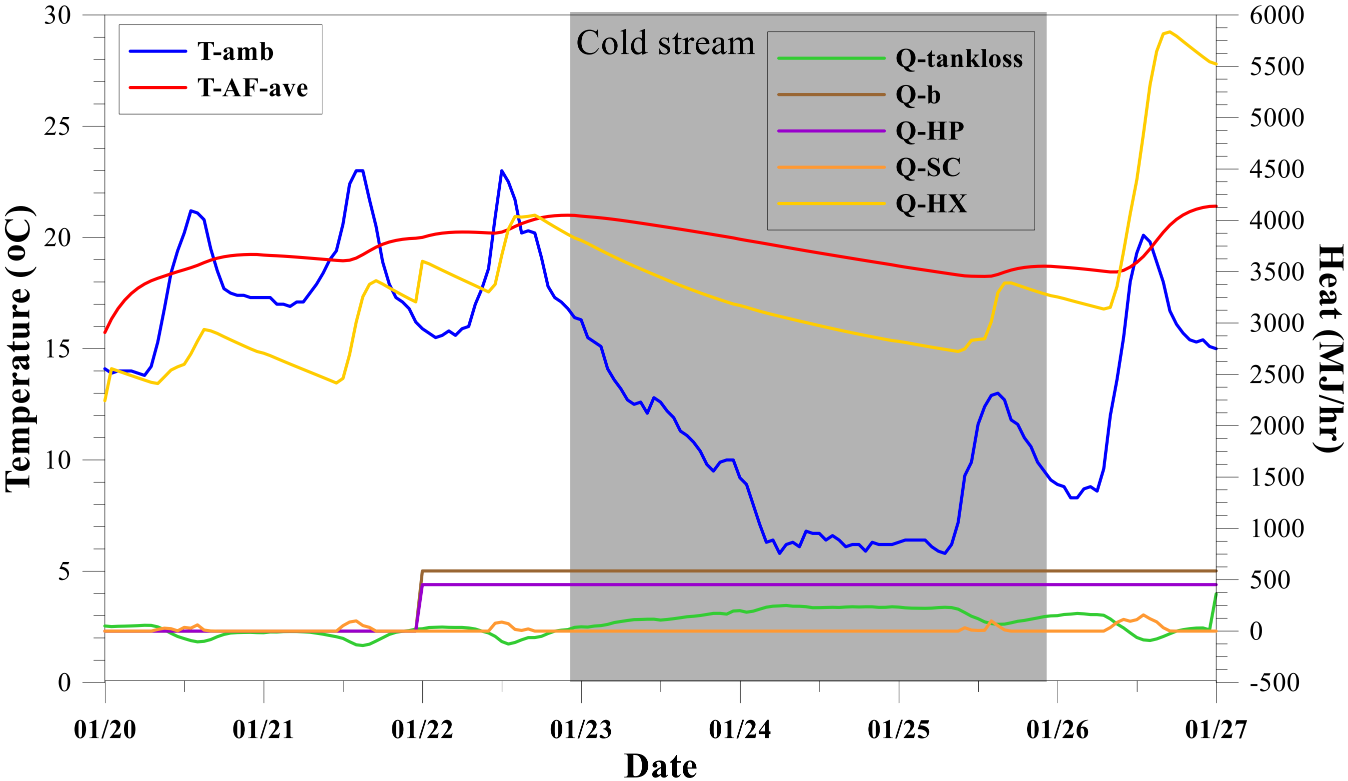
Total heat gain (MJ)	
290B-Sys.	1.25E+05
HP-162B-Sys.	1.26E+05
SC-HP-162B-Sys.	1.28E+05
SC-HP-37B-Sys.	7.29E+04

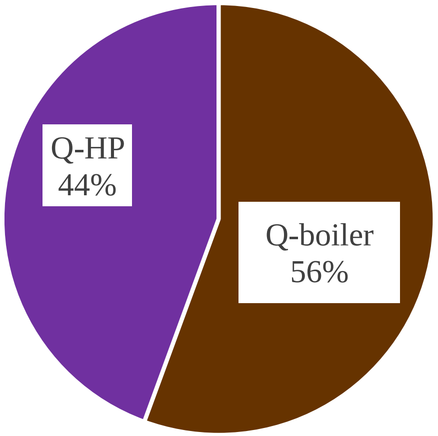

Boiler
HP
Heat exchanger (HX)
Aquatic farm
Heat exchanger (HX)
Heat

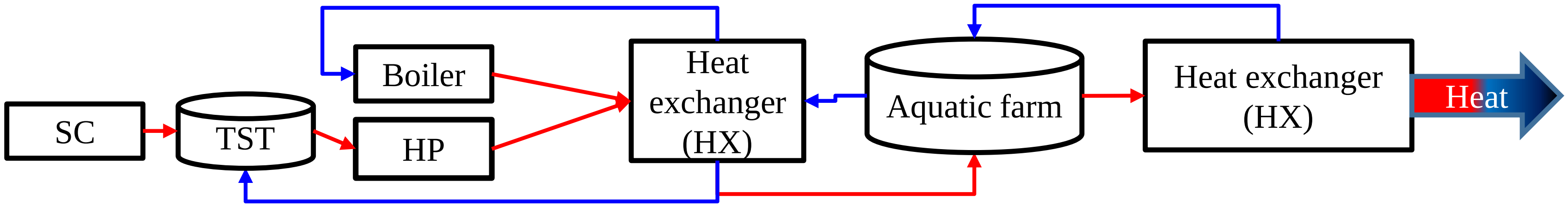

Cold stream
Temperature (oC)
Heat (MJ/hr)
Date
T-amb
T-AF-ave
Q-b
Q-tankloss
Q-HP
Q-HX
30
25
20
15
10
5
0
1200
1000
800
600
400
200
0
-200
01/20
01/21
01/22
01/23
01/24
01/25
01/26
01/27


Q-HP
44%
Q-boiler
56%

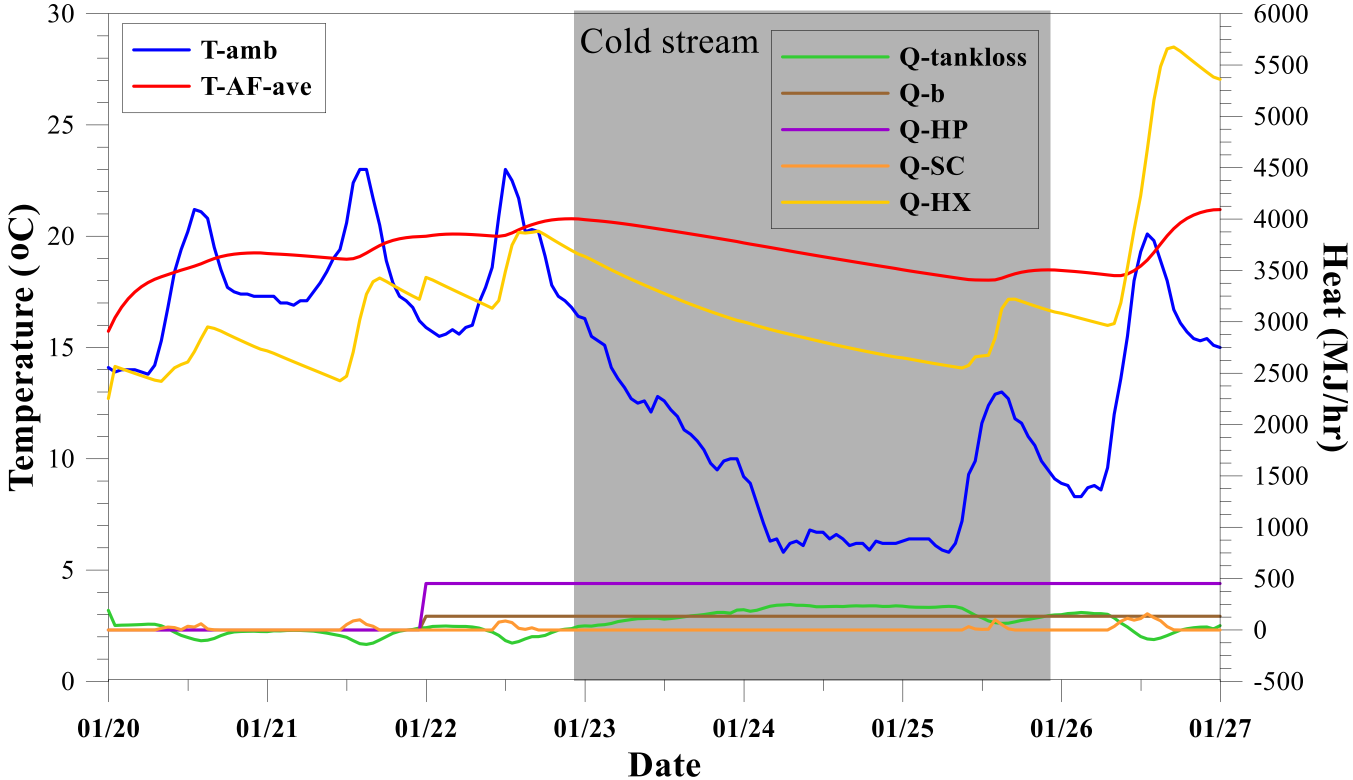

SC
TST
Boiler
HP
Heat exchanger (HX)
Aquatic farm
Heat exchanger (HX)
Heat


Cold stream
T-amb
T-AF-ave
Q-tankloss
Q-b
Q-HP
Q-SC
Q-HX
Temperature (oC)
Heat (MJ/hr)
Date
01/20
01/21
01/22
01/23
01/24
01/25
01/26
01/27

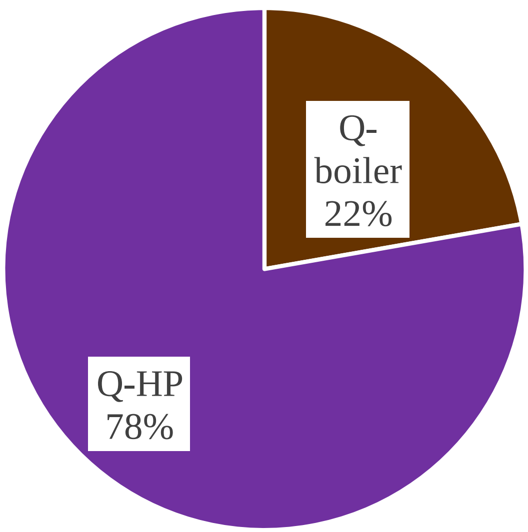

Q-HP
44%
Q-boiler
56%



SC
TST
Boiler
HP
Heat exchanger (HX)
Aquatic farm
Heat exchanger (HX)
Heat



Cold stream
T-amb
T-AF-ave
Q-tankloss
Q-b
Q-HP
Q-SC
Q-HX
Temperature (oC)
Heat (MJ/hr)
Date
01/20
01/21
01/22
01/23
01/24
01/25
01/26
01/27
0
5
10
15
20
25
30
-500
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000



Q-boiler 22%
Q-HP 78%

- 1公頃深水式養殖 可養虱目魚2.2萬尾與105萬尾白蝦 [1]
- 虱目魚46.05元/公斤、白蝦17.87元/公斤
  (13.815元/300g虱目魚尾[3]、0.8935元/50g白蝦尾[4])

→ 0.1250 公頃 可養 0.275 萬尾虱目魚與13.125萬尾白蝦

→虱目魚3.7991萬與白蝦11.7272萬元 →共15.5263萬元

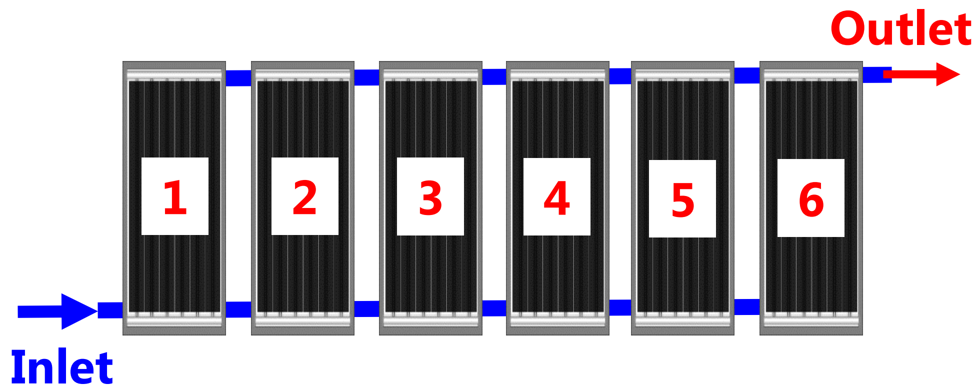
- 遇到一次寒流，少賺15.5263萬元

Total parameters of Heating system

		AF-1	AF-2	AF-3-162B	AF-3-37B
Total heat	Heat (MJ)	125012.693	125673.206	127561.057	72849.700
Heat gain from each source					
Q_SC	Heat (MJ)	0.000	0.000	1887.851	1887.851
Q_HP	Heat (MJ)	0.000	54757.530	54757.530	54757.530
Q_Boiler	Heat (MJ)	125012.693	70915.676	70915.676	16204.319
Proportion of each heat source					
Q_SC	%	0%	0%	1%	3%
Q_HP	%	0%	44%	43%	75%
Q_Boiler	%	100%	56%	56%	22%
Investment cost					
Solar collectors	(NTD)	-	-	1,000.000 k	1,000.000 k
Heat pump	(NTD)	-	60.000 k	600.000 k	600.000 k
20-tons TST	(NTD)	-	-	200.000 k	200.000 k
Circulating motor	(NTD)	-	10.000 k	10.000 k	10.000 k
System installation fee	(NTD)	-	200.000 k	200.000 k	200.000 k
Boiler	(NTD)	450.000 k	300.000 k	300.000 k	150.000 k
Operating cost					
Electricity	(kWh)	0.000	15151.200	4313.615	4313.615
Electricity fee	(NTD)	-	76.211 k	21.697 k	21.697 k
Diesel oil	(Liter)	3556.954	2005.806 k	2005.806	458.329
Diesel oil	(NTD)	95.326	53.756 k	53.756 k	12.283 k
Total cost	(NTD)	545.326	699.966 k	2,385.453 k	2,193.981 k
Assume NTD 155.263 k per 3-months; Assume one cold stream per year					
Payperiod year	(year)	4	5	15	14
CO_2 emission from diesel oil	(kg)	9390	5295	5295	1210
CO_2 emission from diesel oil during payperiod year	(kg)	32982	23873	81357	17098

Simulation in TRNSYS - Validation solar collectors

- Most efficiency arrangement in Tainan is a group of six panel each.



Panels Number	GHI (W/m^2)	Mass flowrate (kg/m^3)	Collector area (m^2)	Raising temperature (°C)	Efficiency (--)
1st	861.6	0.0198	1.91	2.975	0.539
2nd				2.471	0.447
3rd				1.625	0.294
4th				1.038	0.188
5th				1.491	0.27
6th				-2.653	-0.48

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Simulation in TRNSYS
- Validation heat pump (HP)

Parameter	Value	Parameter	Value
Rated compressor power	1.7 kW	Total air flow rate	717 L/s
Rated heat capacity	7 kW	Blower power	0.184 kW

試驗依據 CNS15466 空氣源式熱泵熱水器之性能試驗			
機型	GT-SKR020B6-10		
熱泵熱水器分類	循環加熱式		
性能試驗方法	半穩態性能試驗法		
額定加熱能力試驗環境條件(平均許可差):	空氣側	環境溫度:7 ℃ (Tair(℃)) ，相對濕度: 80% (Hair(%))	
	水側	初始水溫:9℃(Twater℃)	
額定加熱能力實測值(kW)		主機吹出最大風量(m^3/min)	42.45
		主機出風口乾球 DB(℃)	4.41
4.900		主機出風口濕球 EB(℃)	3.99

Pw (總消耗電量) : 4961kWh
t (加熱時間) : 3.275h