

Appendix VII – Yuen Long Government Primary School

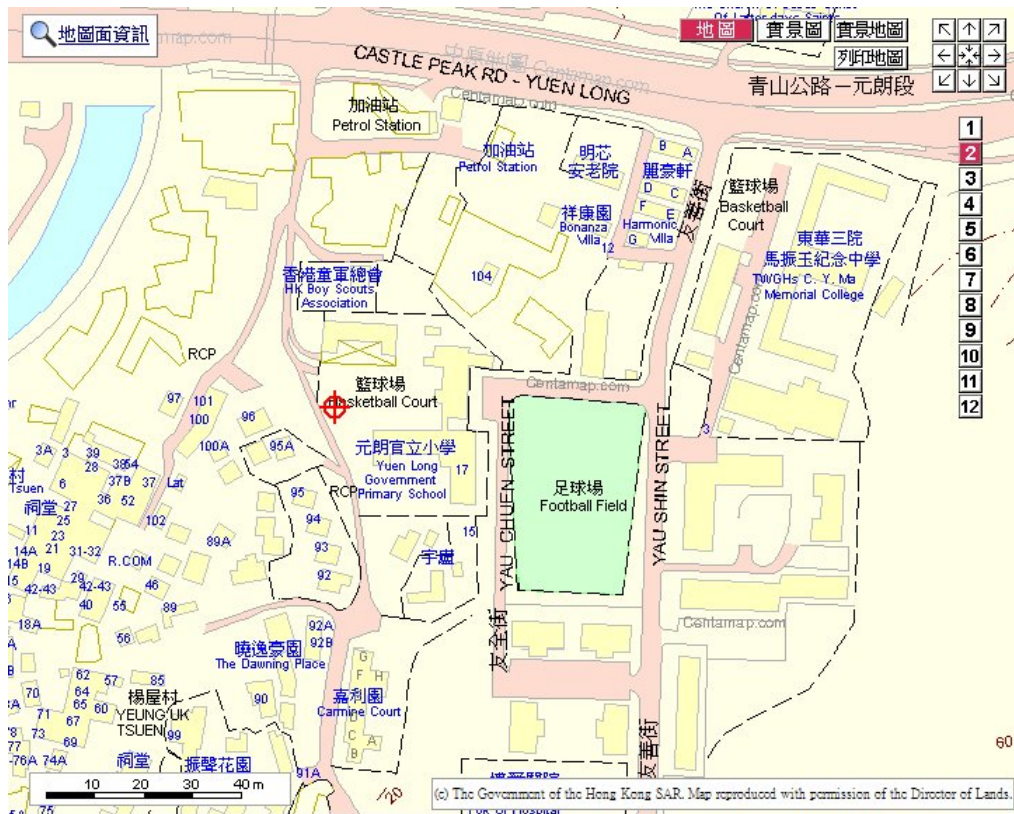


Figure A7.1 Location map and aerial photo of YLGPS
(source: www.centamap.com)



Figure A7.2 Selected site photos of YLGPS

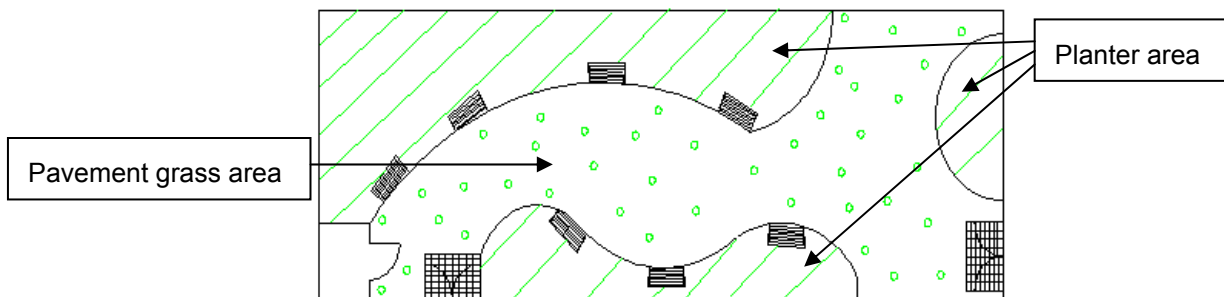


Figure A7.3 Roof garden layout of YLGPS

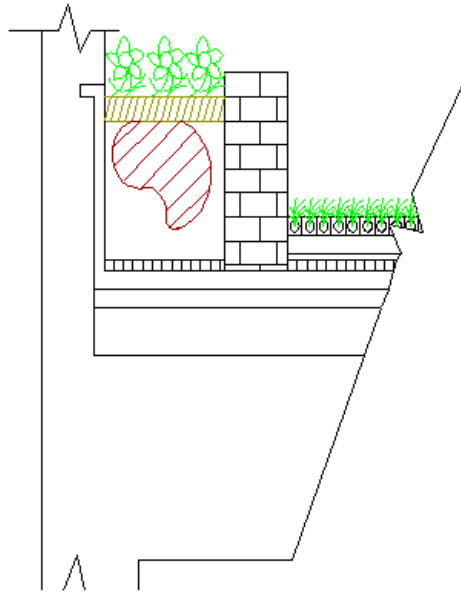


Figure A7.4 Section of the roof garden of YLGPS

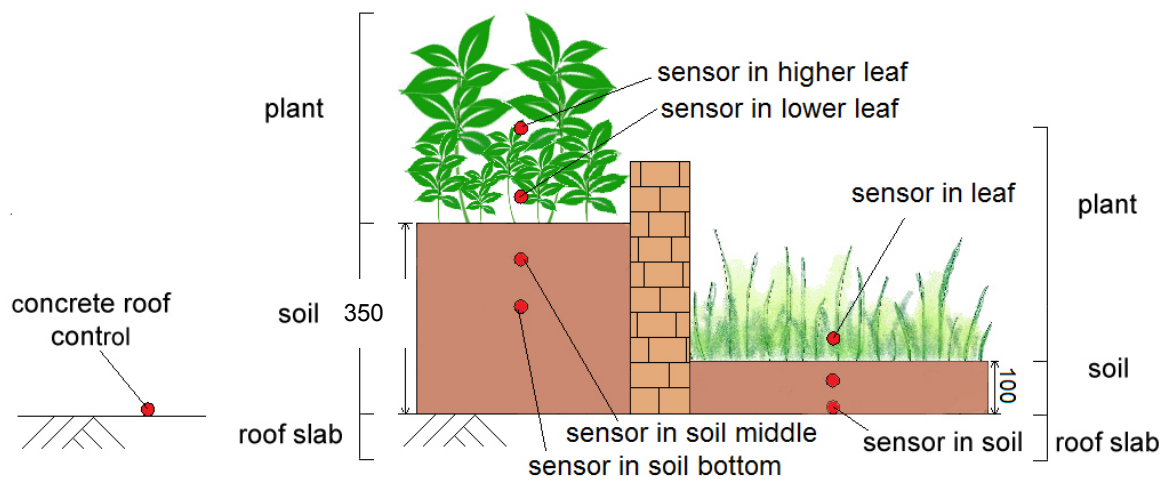


Figure A7.5 Section and sensor positions of the roof garden of YLGPS

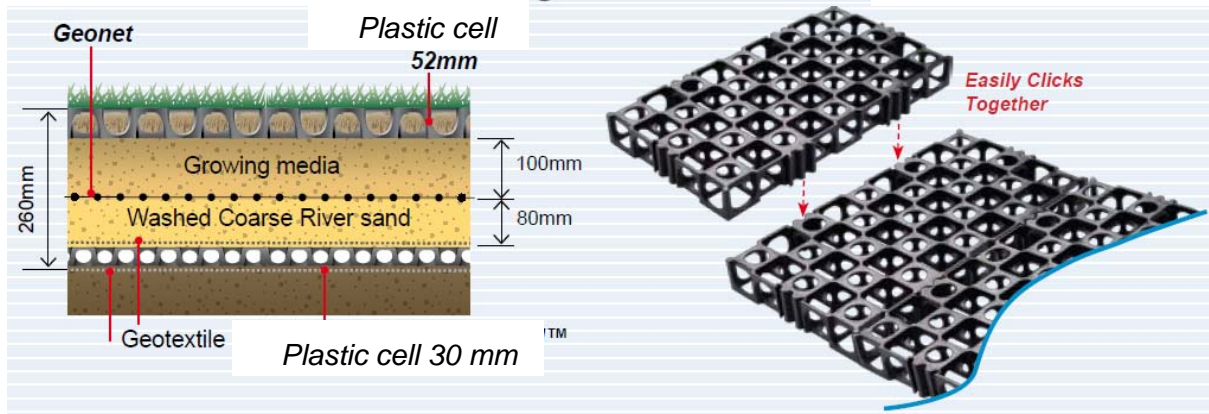
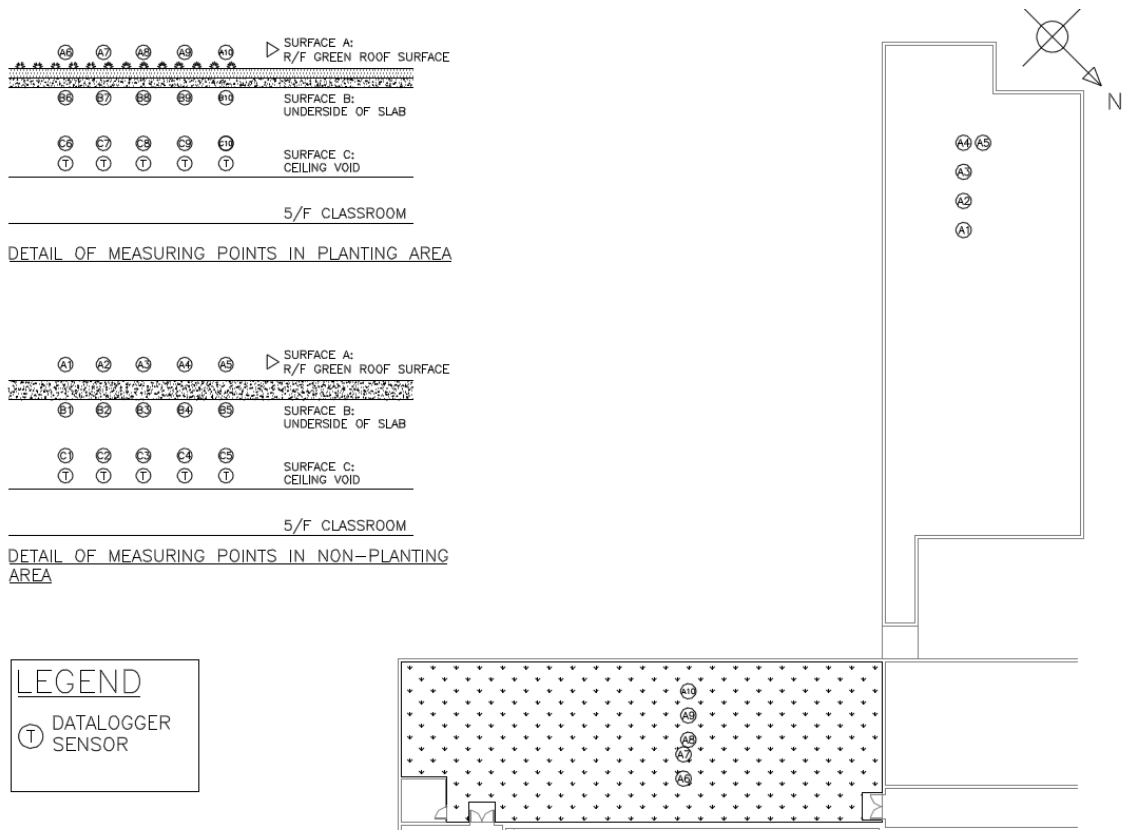
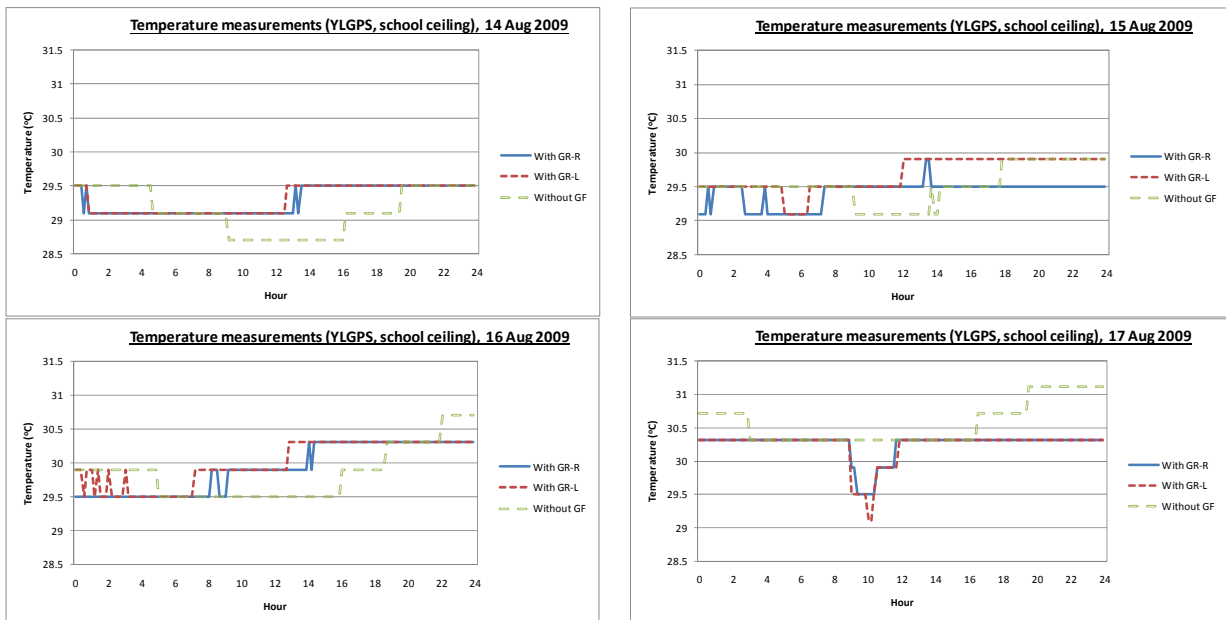


Figure A7.6 Green roof system of YLGPS (Source: www.porous-paving.com.au)



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Figure A7.7 Temperature measuring points of YLGPS from EMSD subcontractor



(Note: GR-R = under planter; GR-L = under grass pavement; Without GF = under control bare roof)

Figure A7.8 Temperature of YLGPS at ceiling below the roof, 14-17 Aug 2009

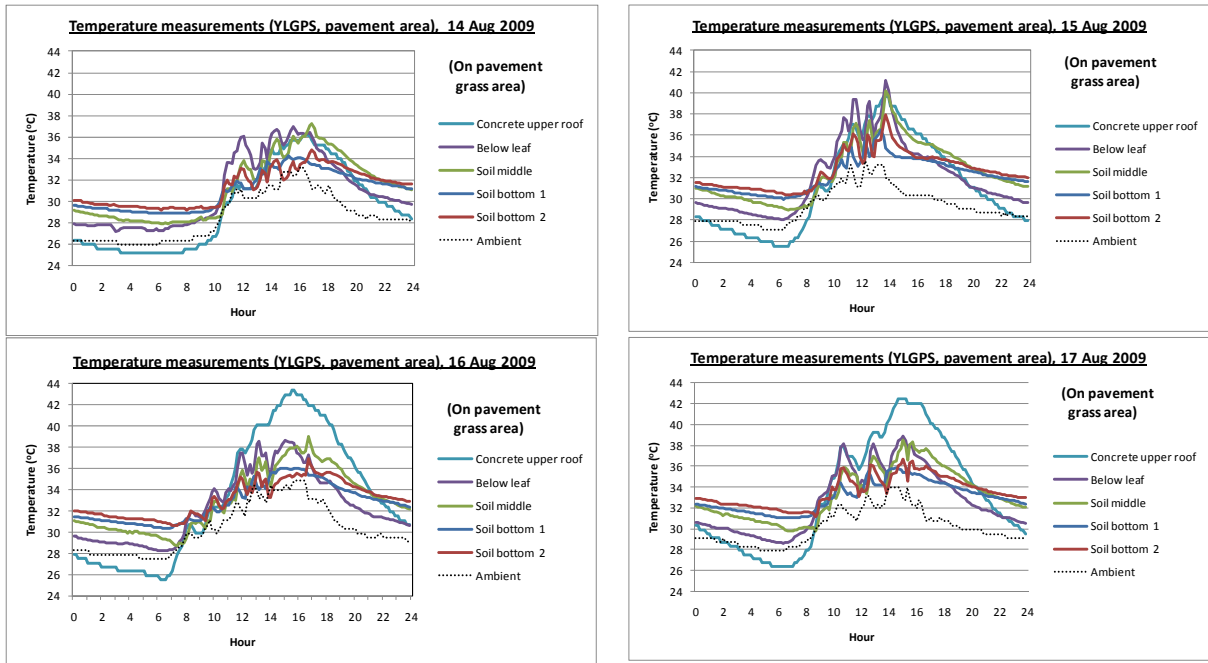


Figure A7.9 Temperature of YLGPS: pavement grass area, 14-17 Aug 2009

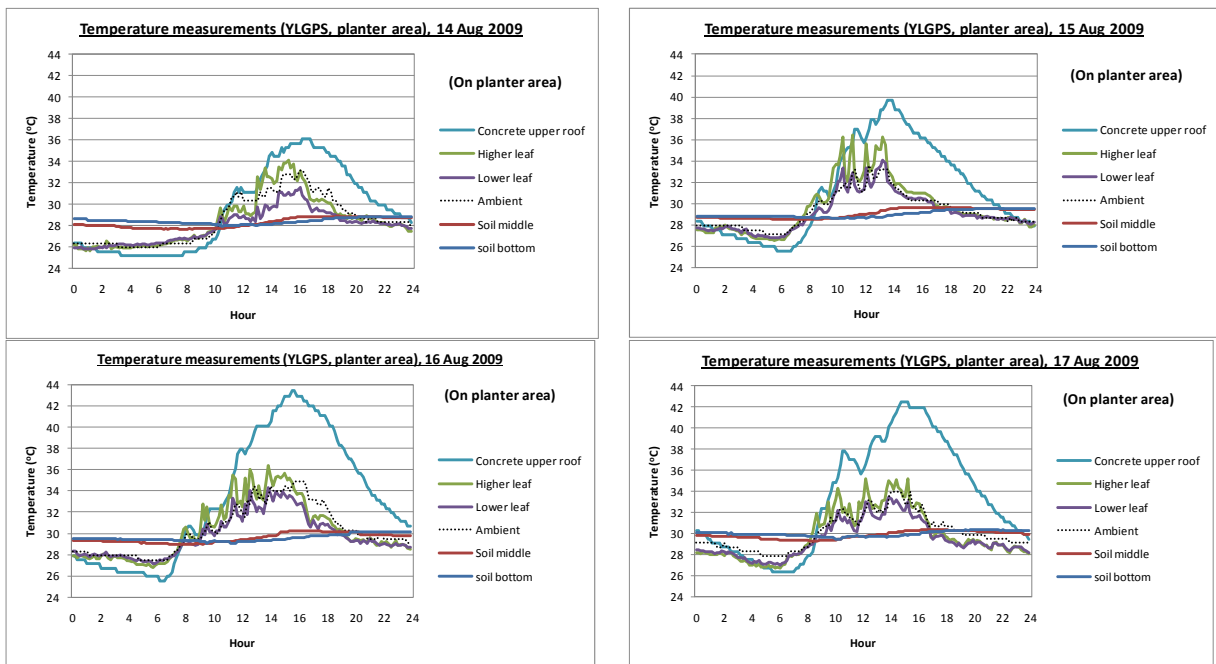


Figure A7.10 Temperature of YLGPS: planter area, 14-17 Aug 2009

Appendix VIII – St. Bonaventure Catholic Primary School



Figure A8.1 Location map and aerial photo of SBCPS
(source: www.centamap.com)



Overview of assembly hall (5 Sep 2009)



Green roof sedum plant (22 Jul 2009)



Extensive green roof (5 Sep 2009)



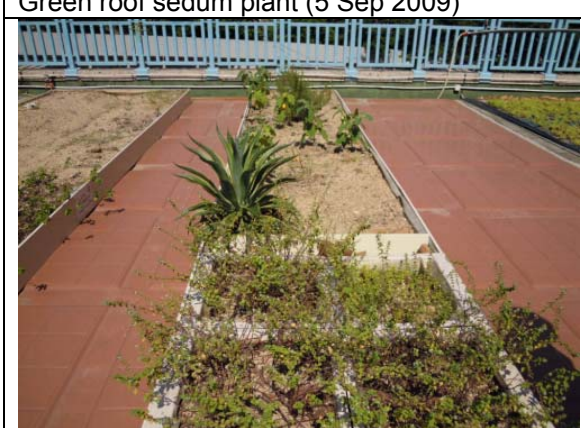
Extensive green roof (5 Sep 2009)



Green roof sedum plant (5 Sep 2009)



Green roof measurements (5 Sep 2009)



Urban farming area (5 Sep 2009)



Urban farming tray with mint (5 Sep 2009)

Figure A8.2 Selected site photos of SBCPS

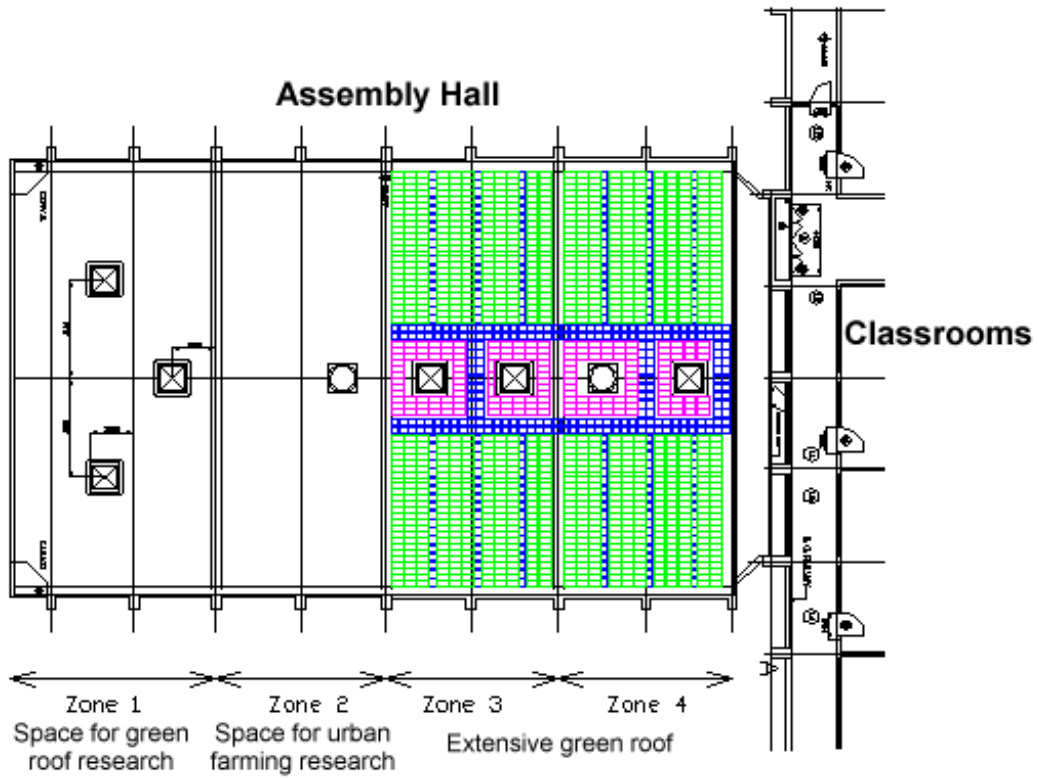


Figure A8.3 SBCPS green roof on the assembly hall

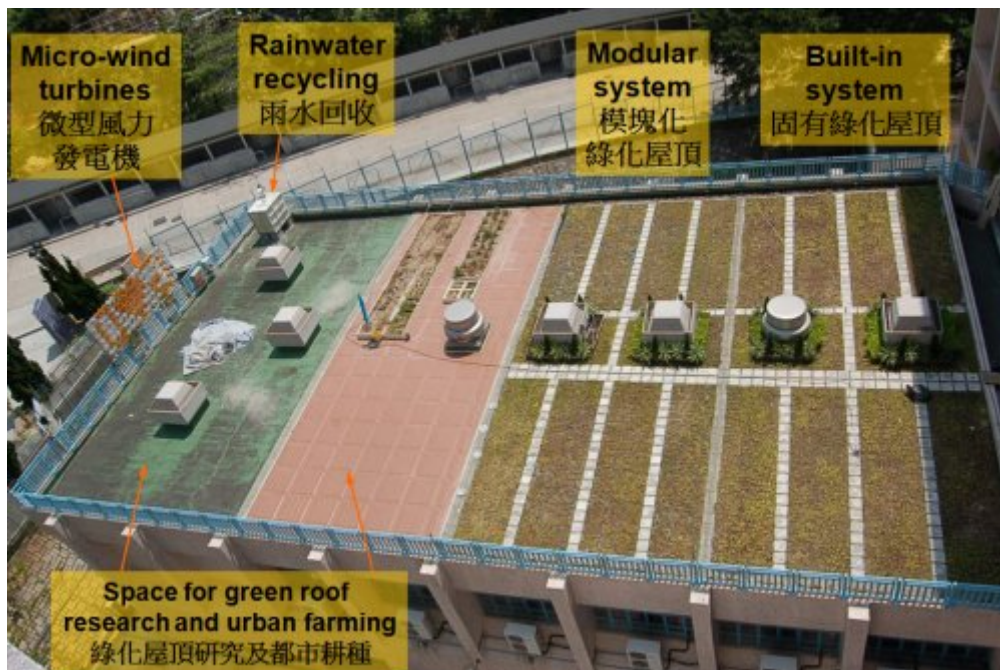


Figure A8.4 Integrated green roof systems at SBCPS

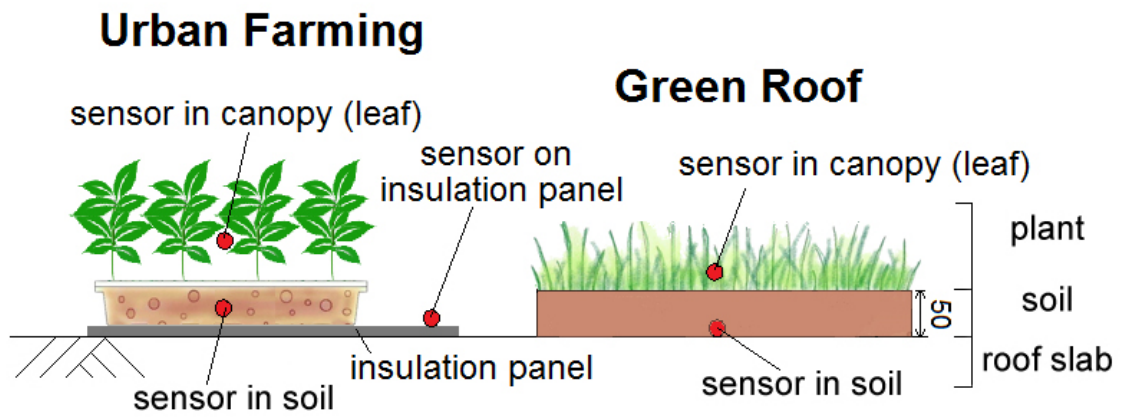


Figure A8.5 Section and sensor positions of SBCPS

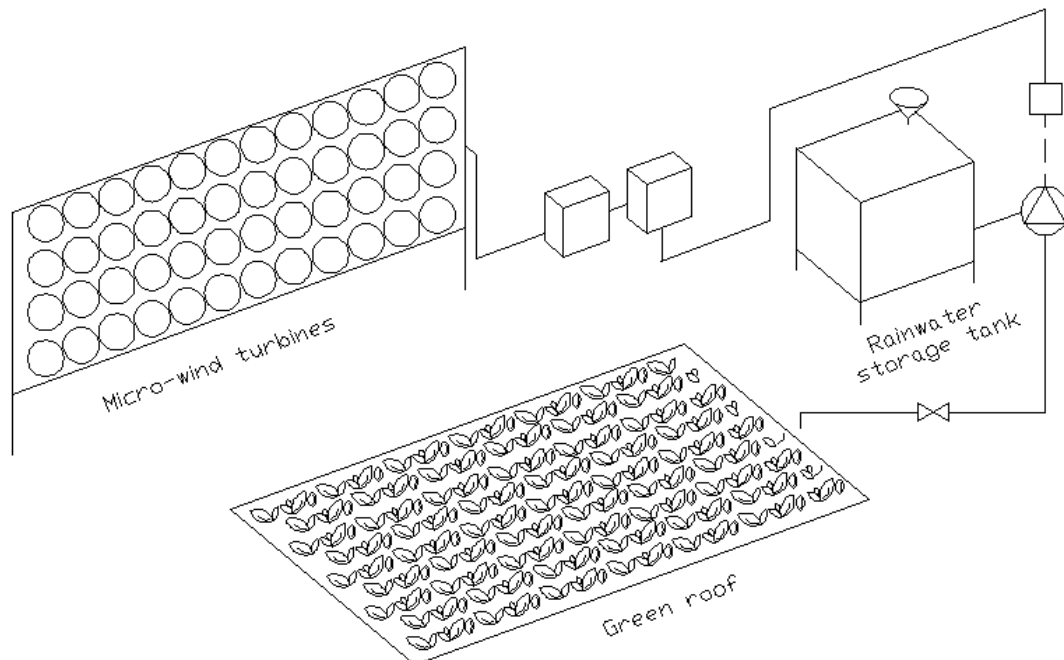


Figure A8.6 Integration of wind energy, rainwater recycling and green roof system at SBCPS assembly hall

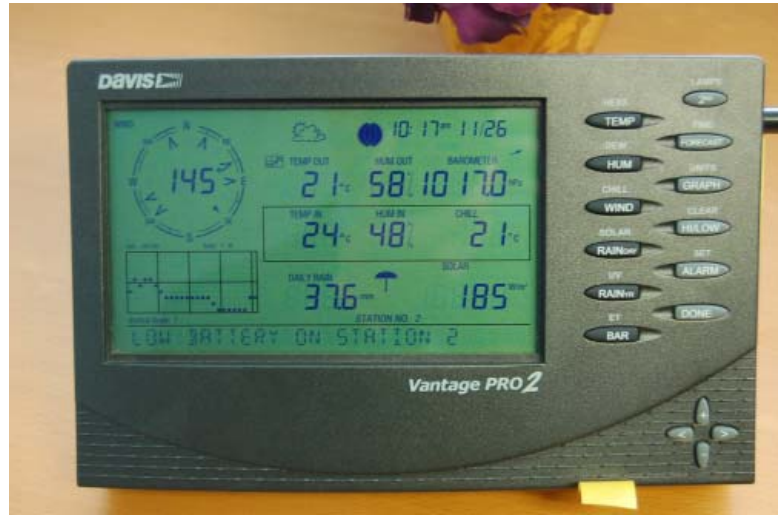


Figure A8.7 Weather station set up at SBCPS

Appendix IX – Infrared Photos of the Green Roof Sites

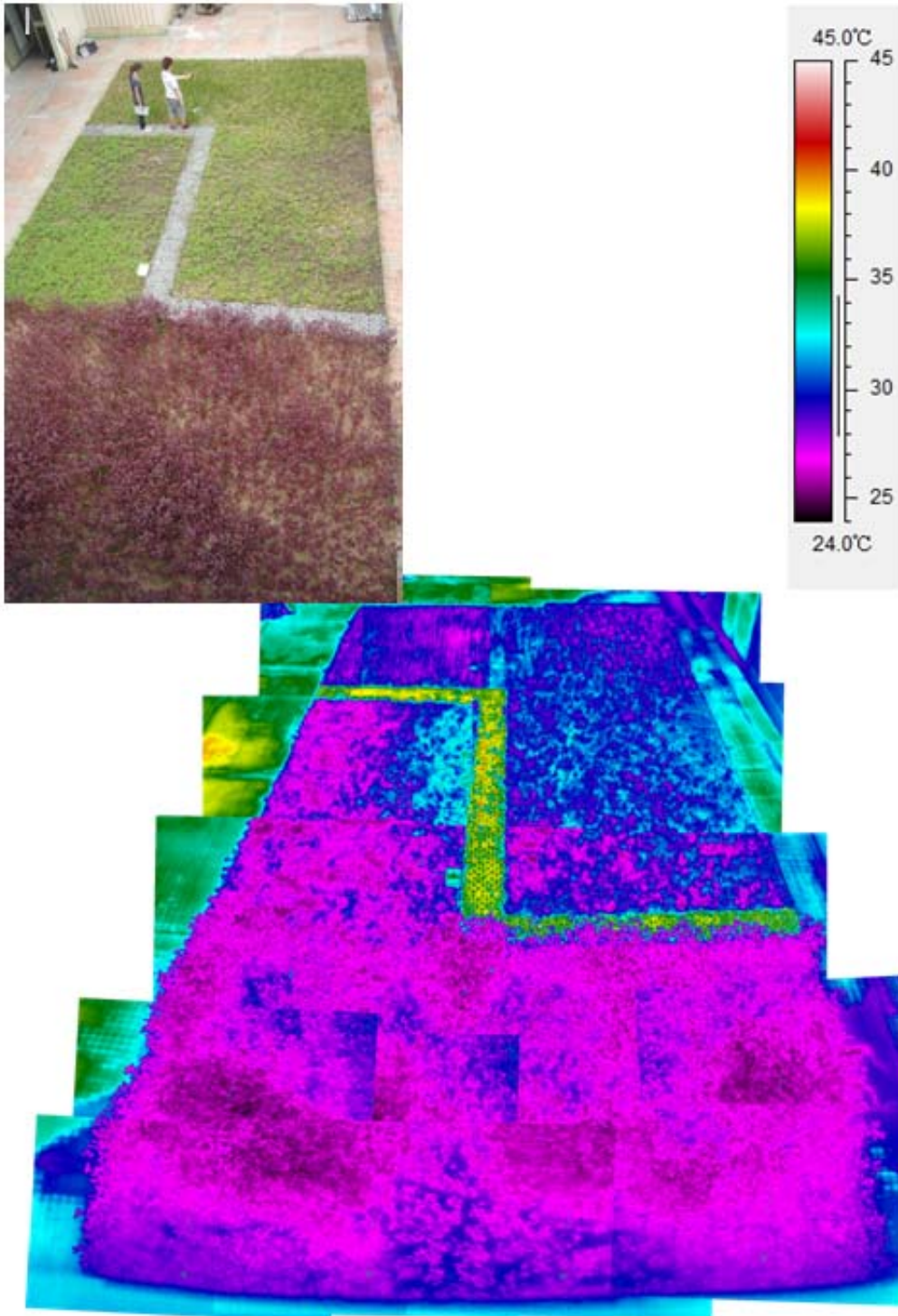


Figure A9.1 Infrared photos of NTK Municipal Office Building

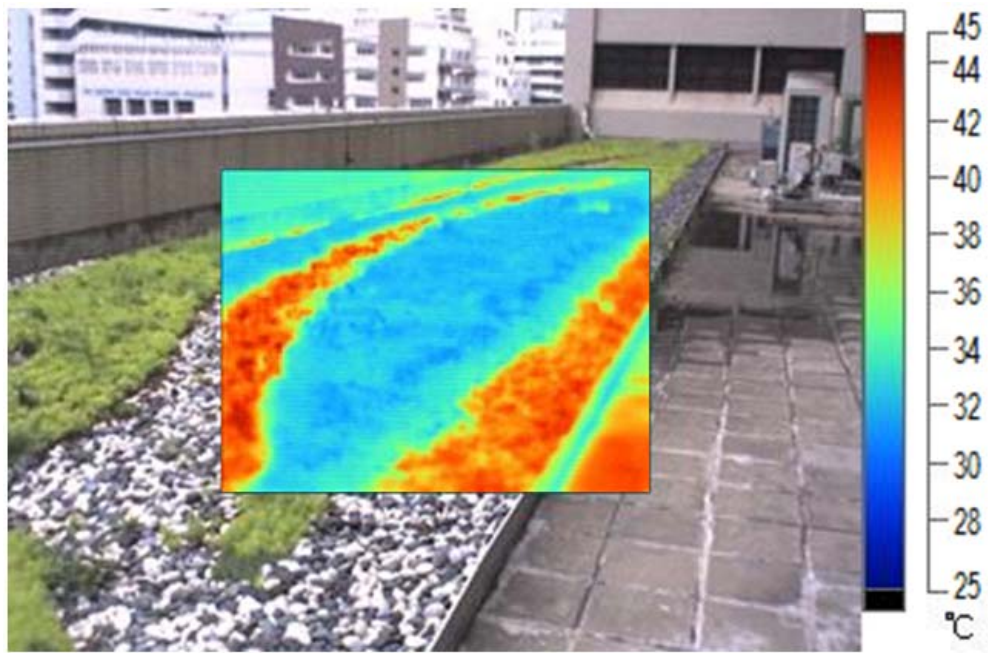


Figure A9.2 Infrared photos of APB Centre

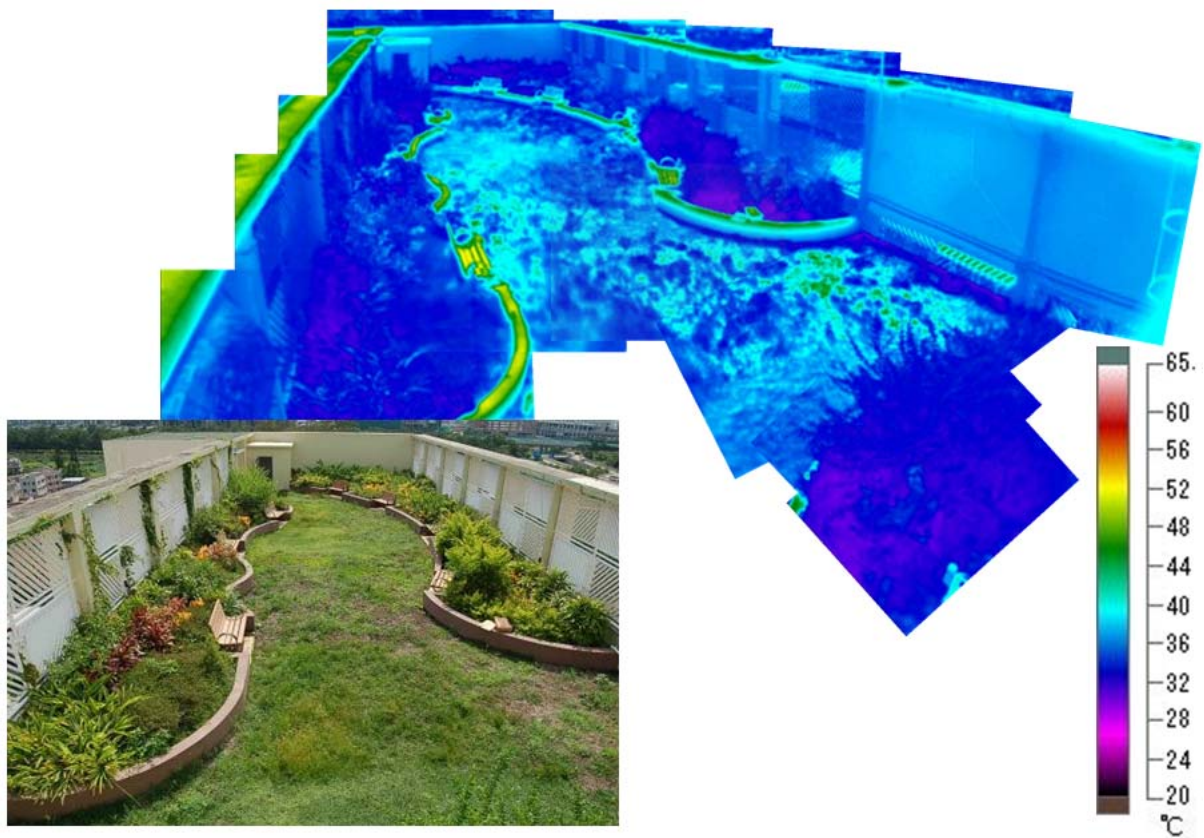


Figure A9.3 Infrared photos of YLGPS roof garden

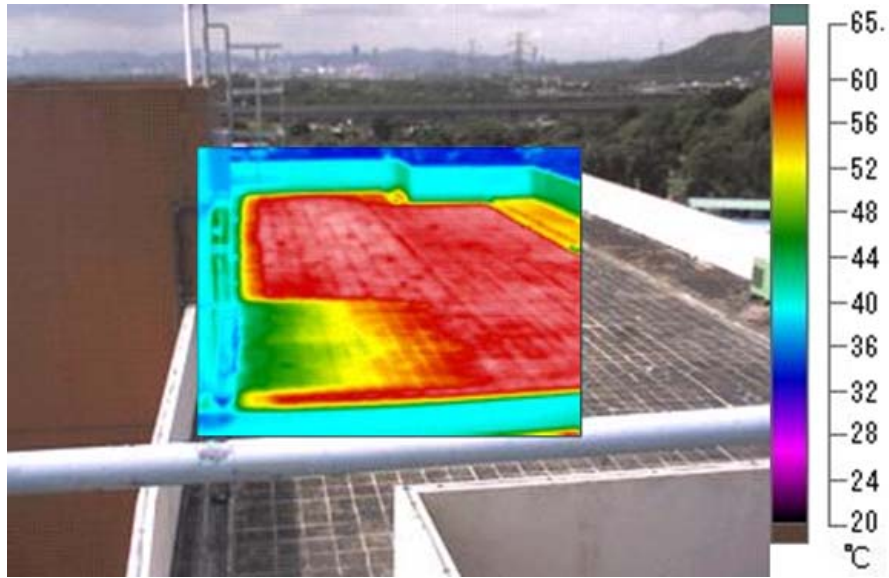


Figure A9.4 Infrared photos of YLGPS control bare roof

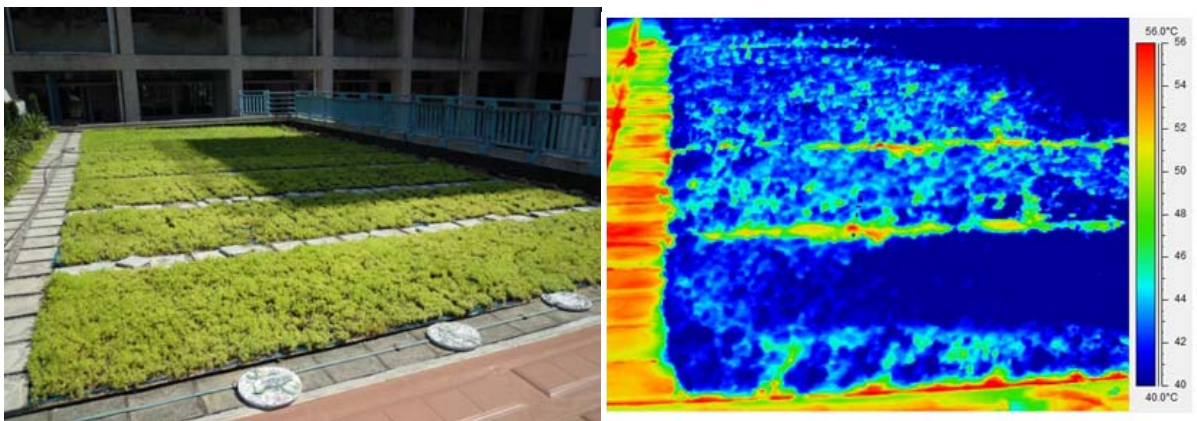


Figure A9.5 Infrared photos of SBCPS green roof

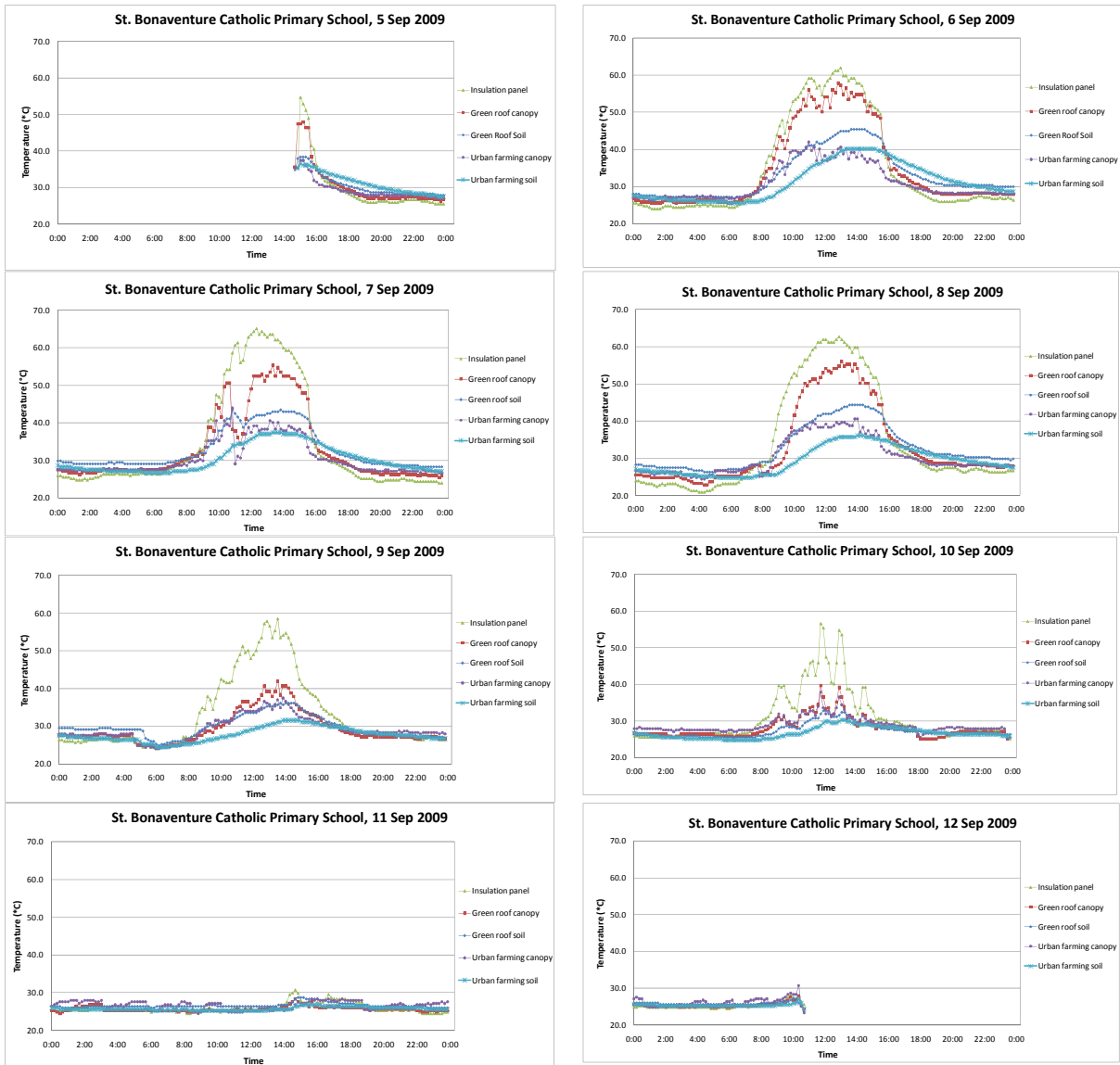
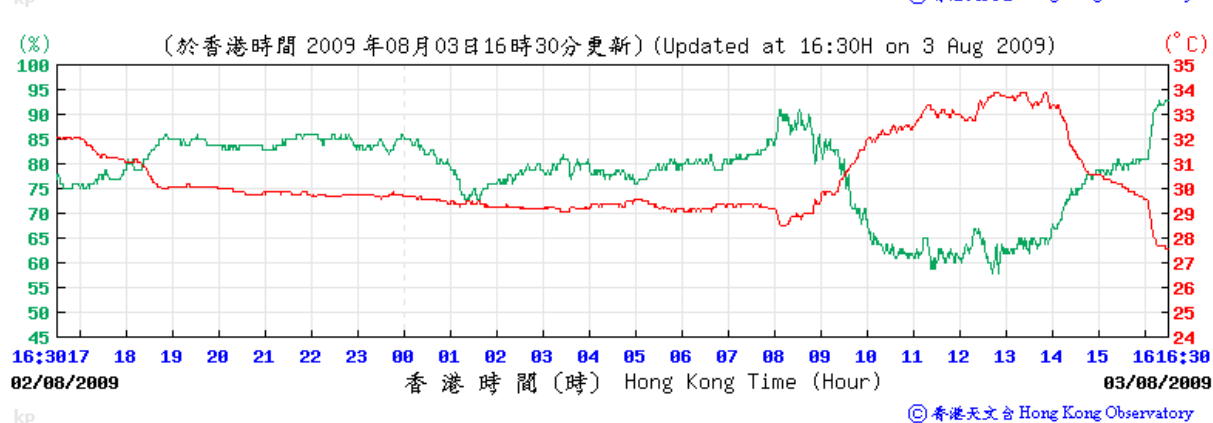
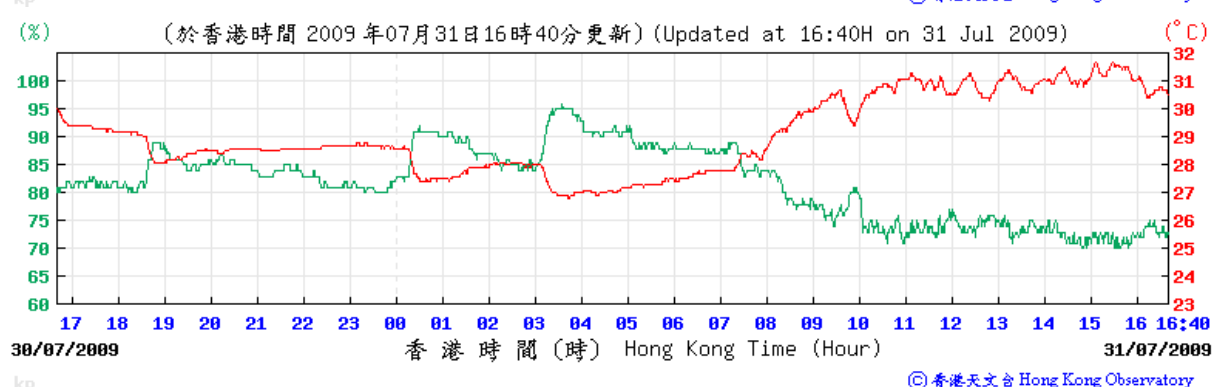
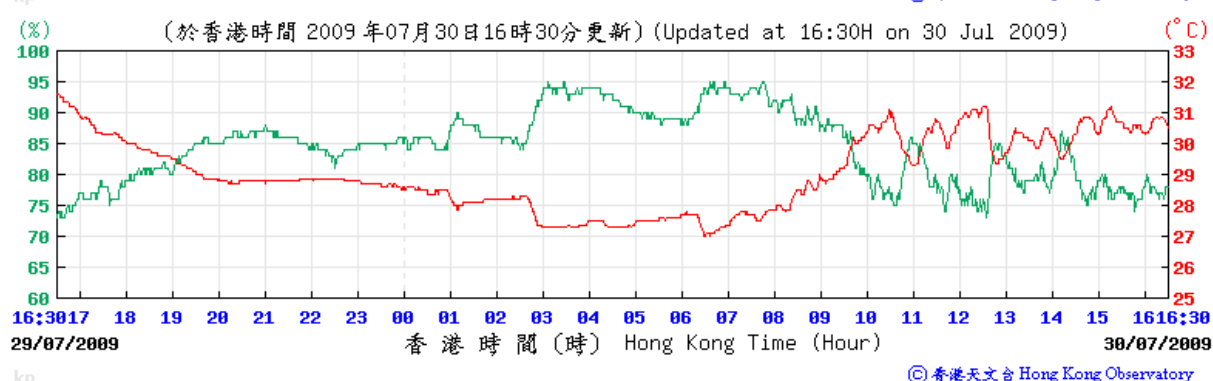
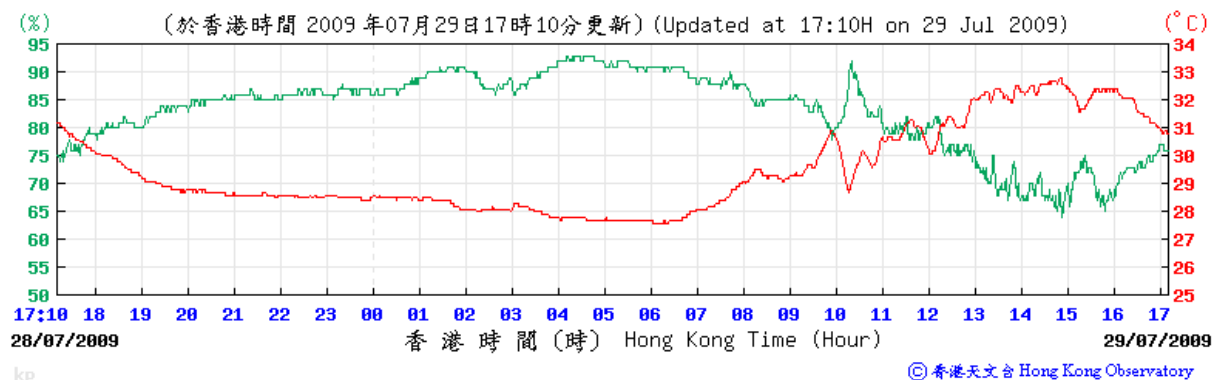


Figure A9.6 Temperature of SBCPS, 5-12 Sep 2009

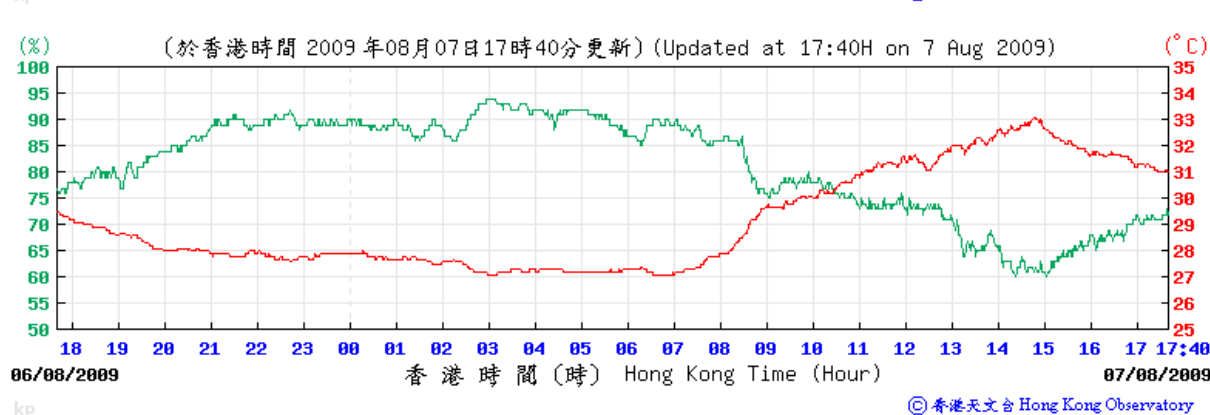
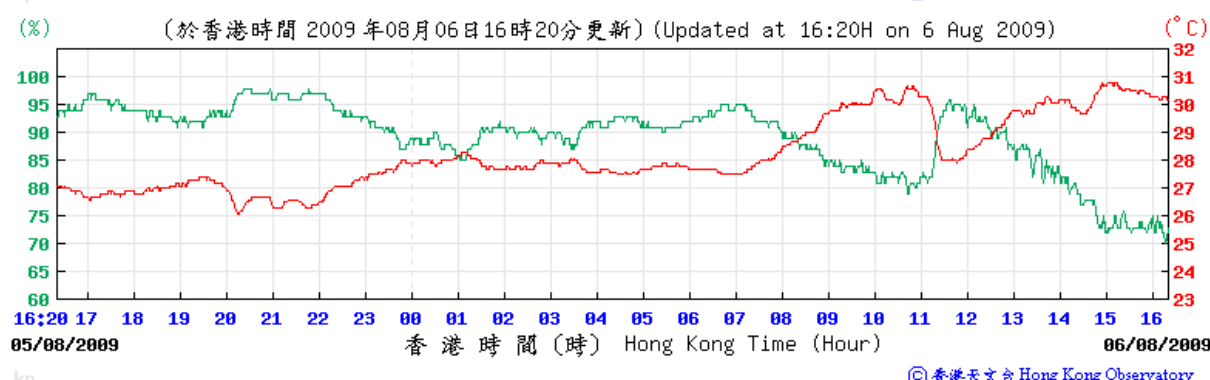
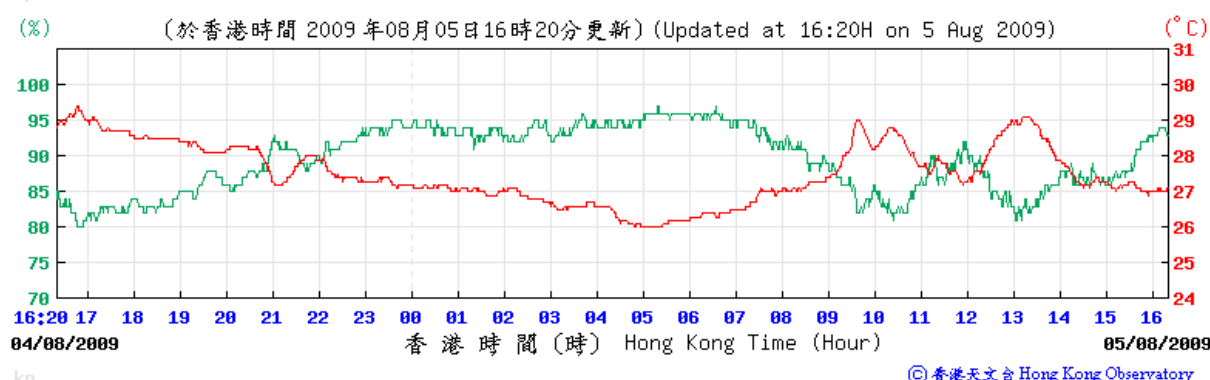
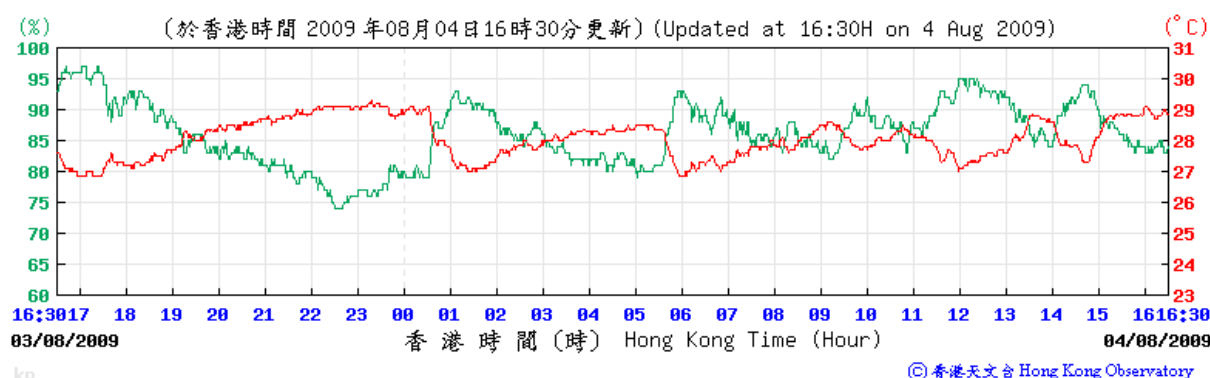
Appendix X – Weather Data from Hong Kong Observation

Temperature and relative humidity at King's Park Weather Station:

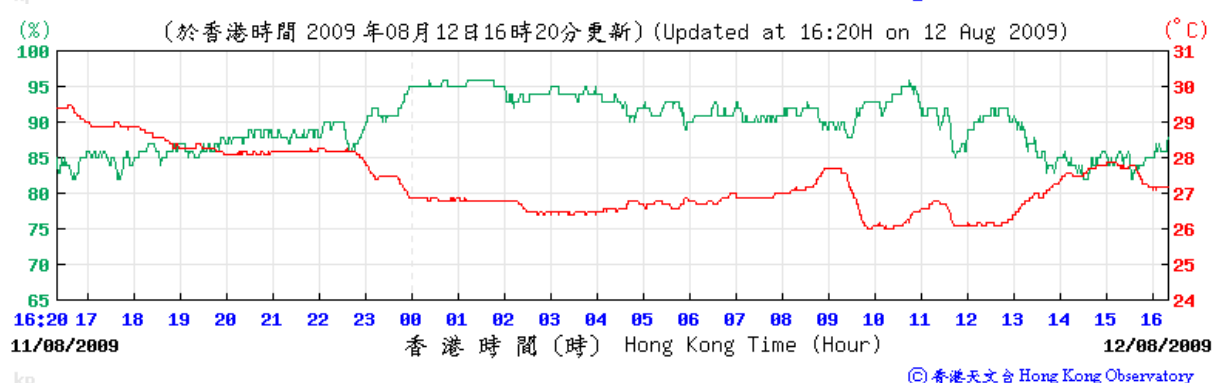
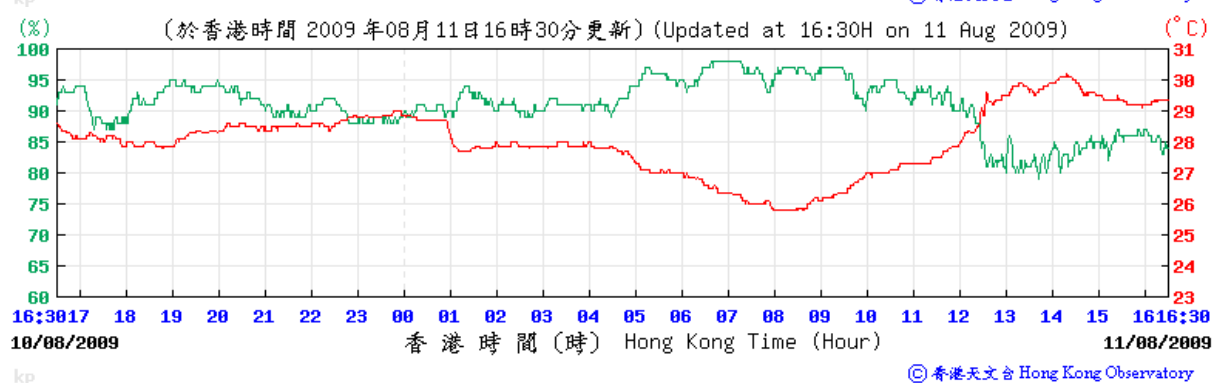
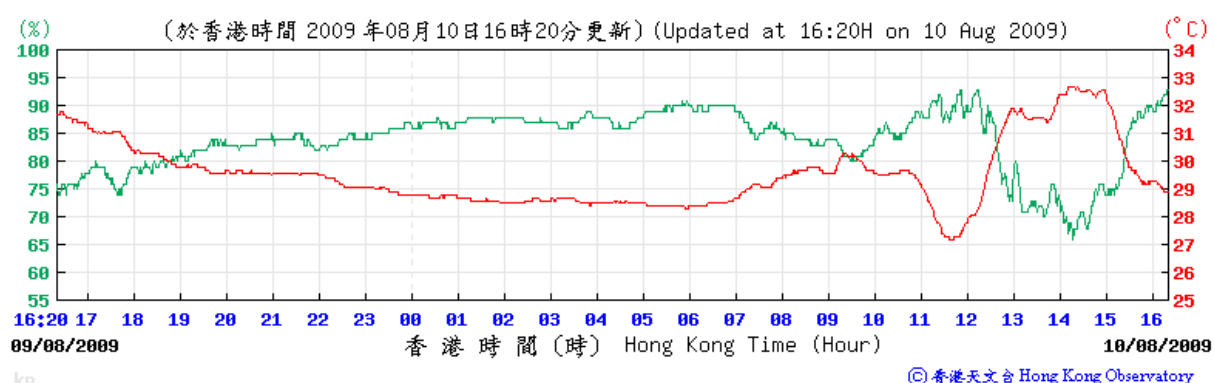
(29 Jul, 30 Jul, 31 Jul and 3 Aug 2009)



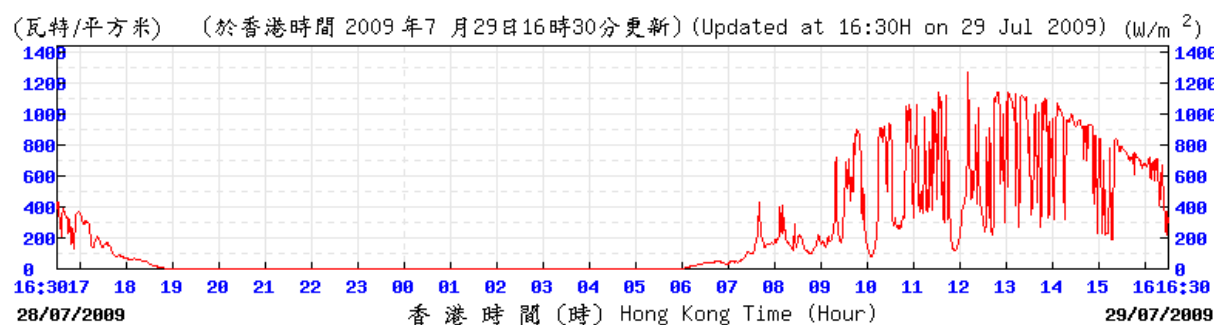
Temperature and relative humidity at King's Park Weather Station:
(4-7 Aug 2009)



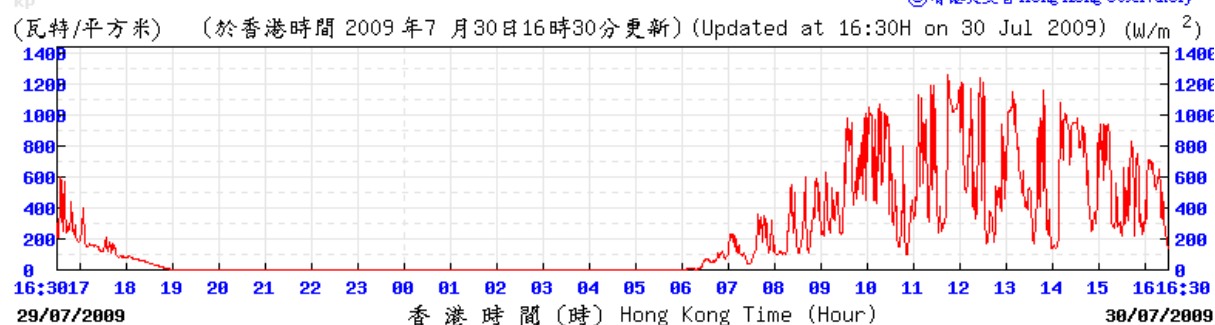
Temperature and relative humidity at King's Park Weather Station:
(10-12 Aug 2009)



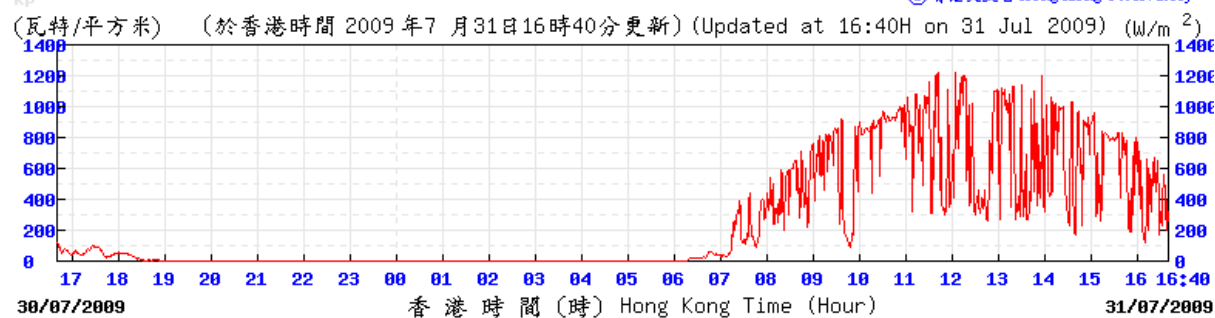
Horizontal global solar radiation at King's Park Weather Station:
(29 Jul, 30 Jul, 31 Jul and 3 Aug 2009)



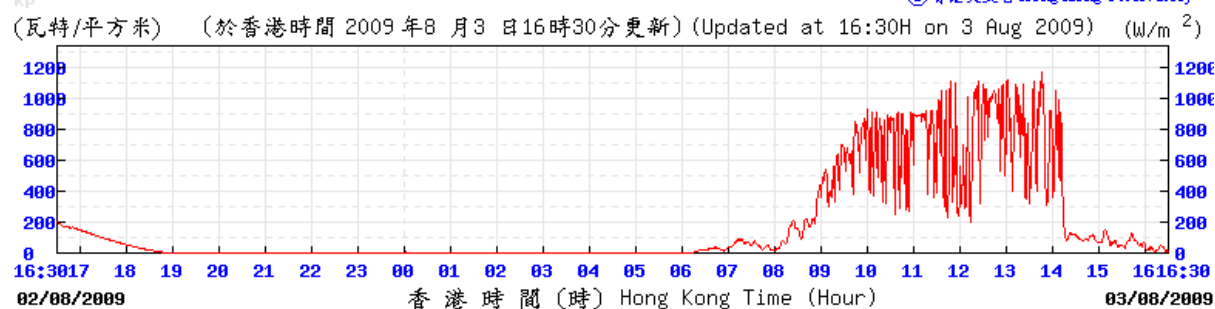
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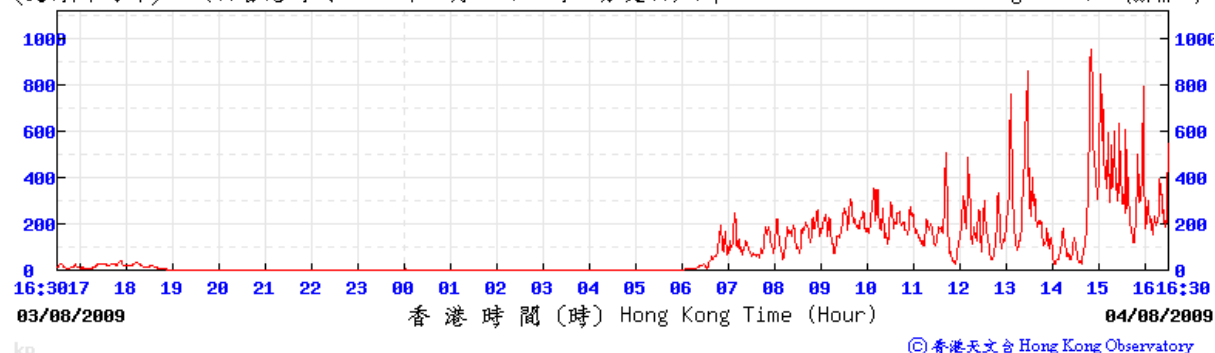
© 香港天文台 Hong Kong Observatory



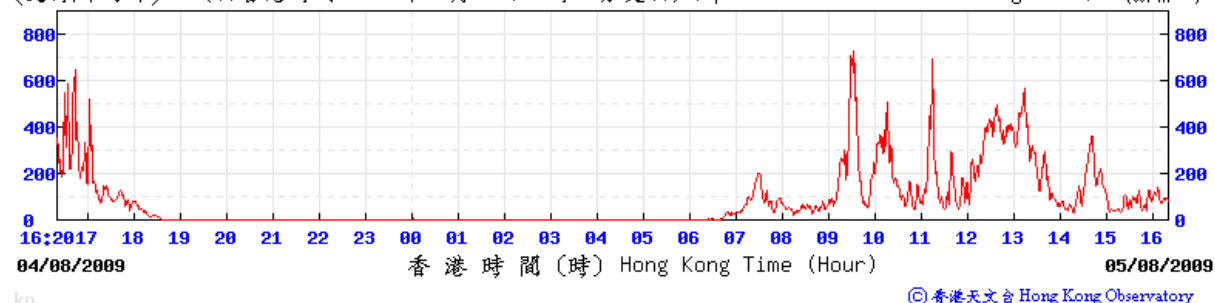
© 香港天文台 Hong Kong Observatory

Horizontal global solar radiation at King's Park Weather Station:
(4-7 Aug 2009)

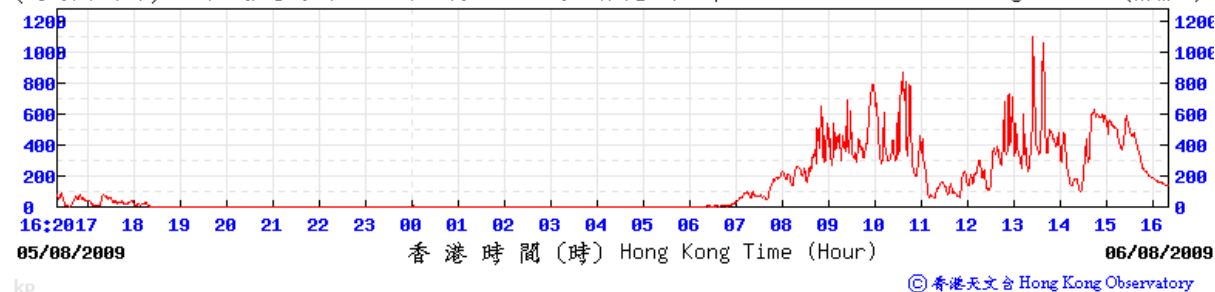
(瓦特/平方米) (於香港時間 2009 年 8 月 4 日 16 時 30 分更新) (Updated at 16:30H on 4 Aug 2009) (W/m^2)



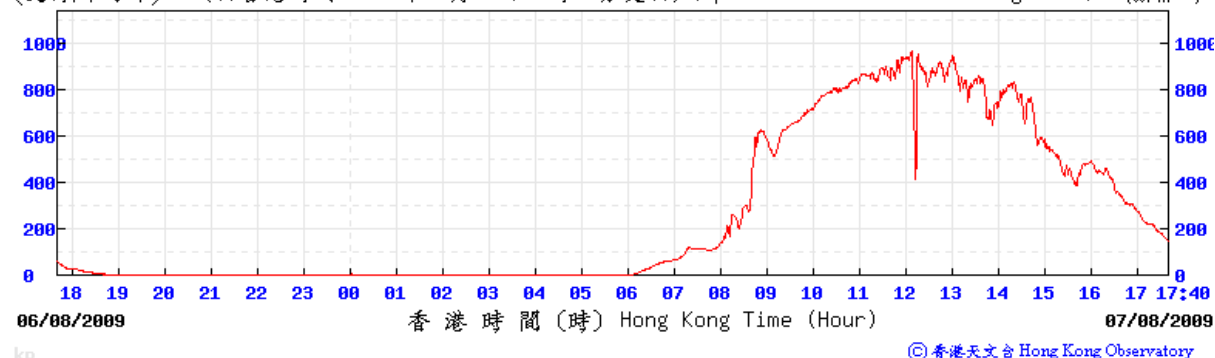
(瓦特/平方米) (於香港時間 2009 年 8 月 5 日 16 時 20 分更新) (Updated at 16:20H on 5 Aug 2009) (W/m^2)



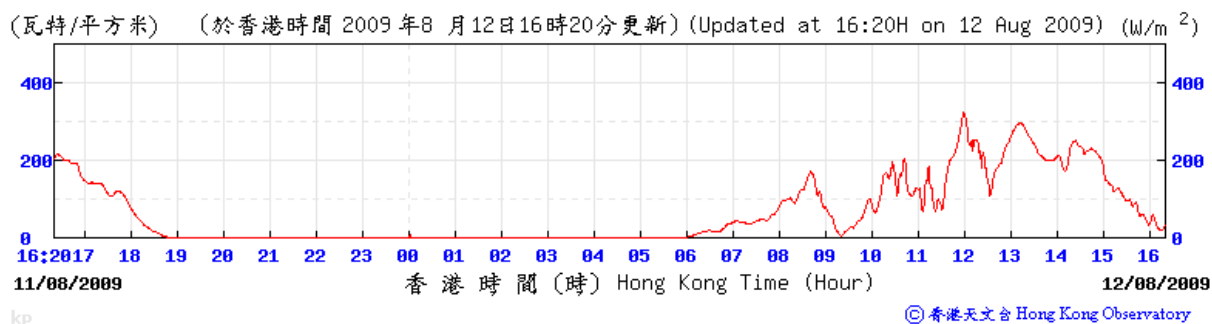
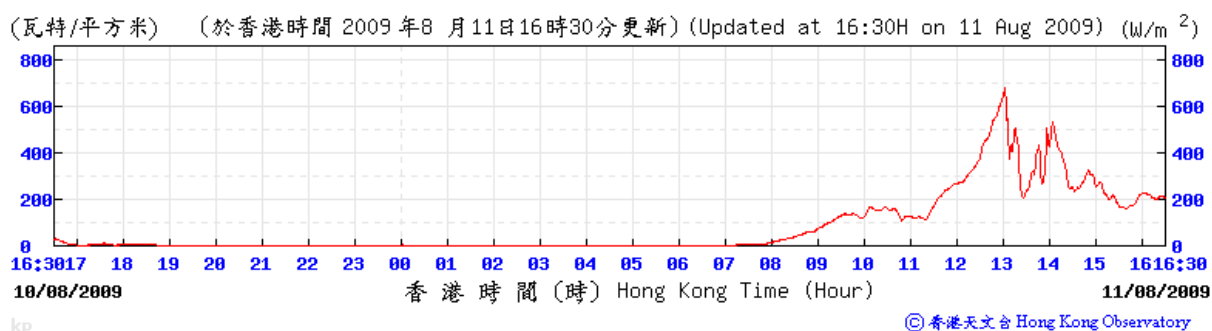
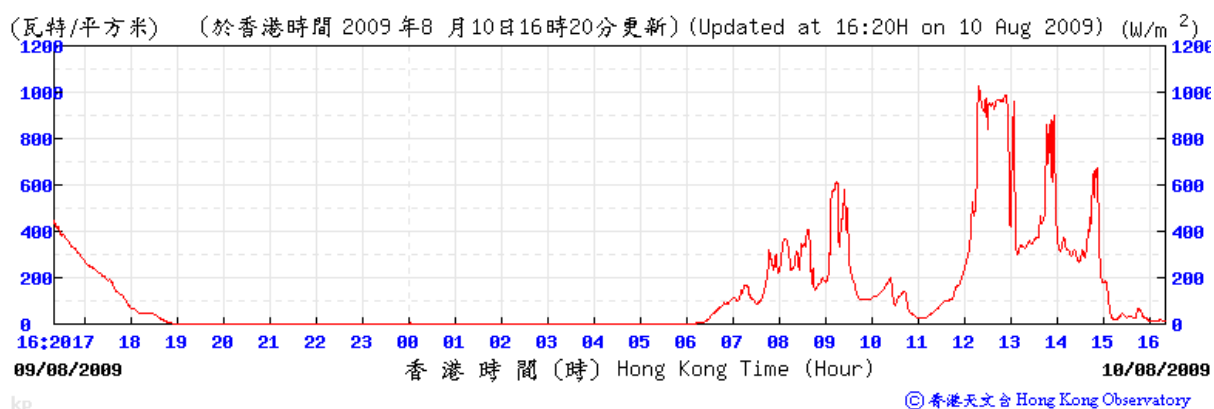
(瓦特/平方米) (於香港時間 2009 年 8 月 6 日 16 時 20 分更新) (Updated at 16:20H on 6 Aug 2009) (W/m^2)



(瓦特/平方米) (於香港時間 2009 年 8 月 7 日 17 時 40 分更新) (Updated at 17:40H on 7 Aug 2009) (W/m^2)



Horizontal global solar radiation at King's Park Weather Station:
(10-12 Aug 2009)



Appendix XI – Manual Measurements by EMSD subcontractor

Manual temperature measurements by EMSD subcontractor (Newland)

To compare the measurement data of the HKU researchers with the manual measurements, the corresponding graphs for the day are shown.

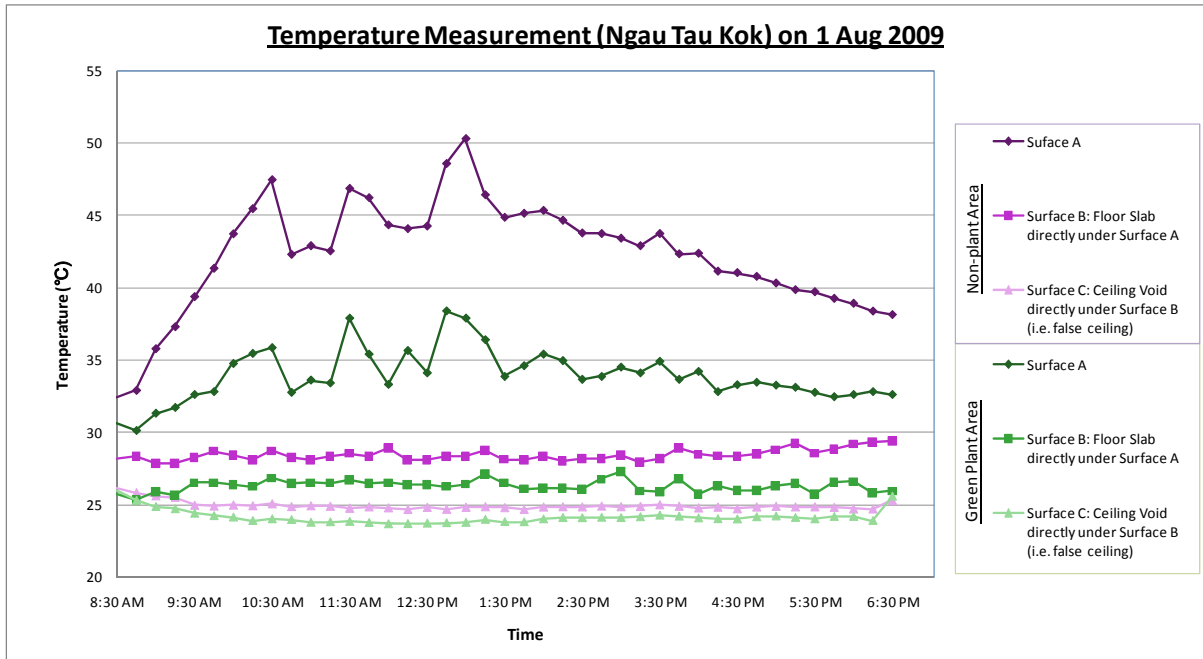


Figure A11.1 EMSD subcontractor's temperature data of NTK Building, 1 Aug 2009

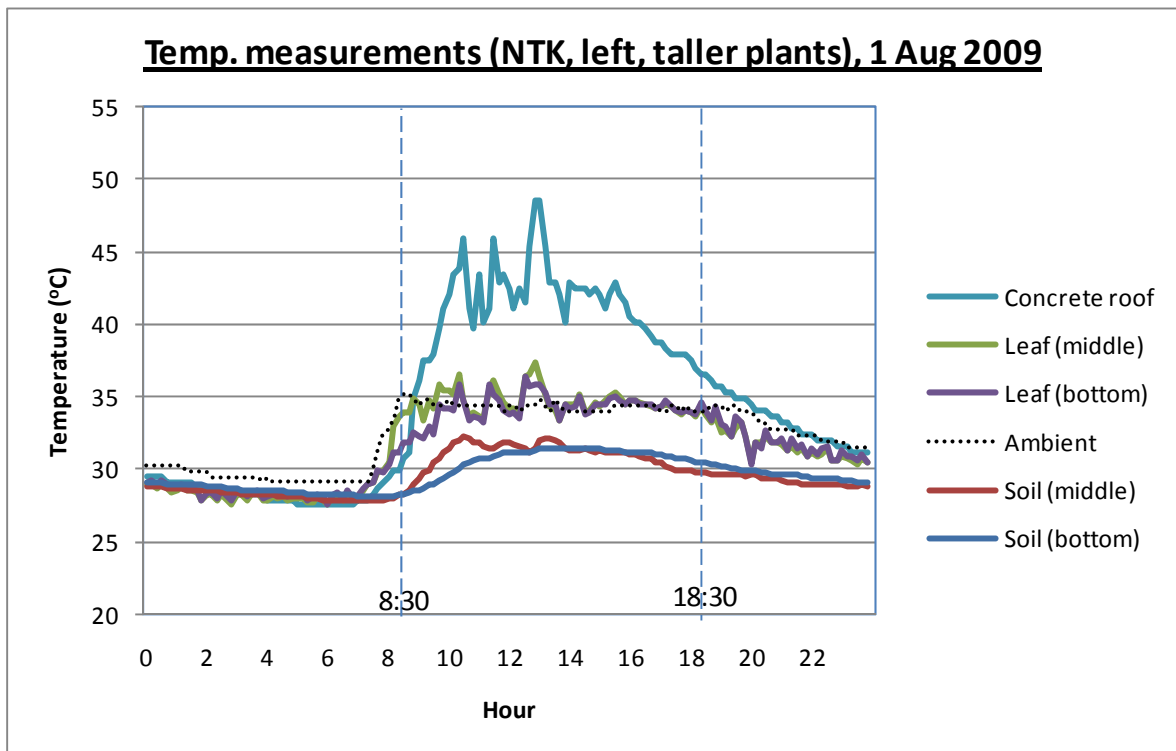


Figure A11.2 Temperature of NTK Building: taller plants, 1 Aug 2009

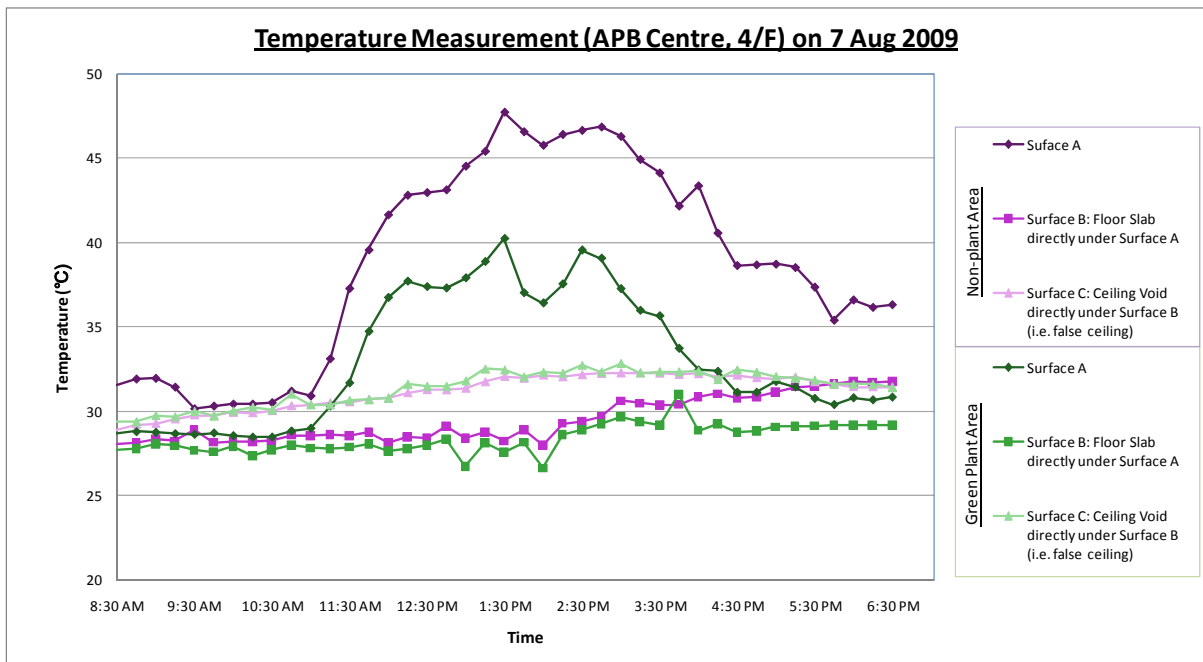


Figure A11.3 EMSD subcontractor's temperature data of APB Centre 4/F, 7 Aug 2009

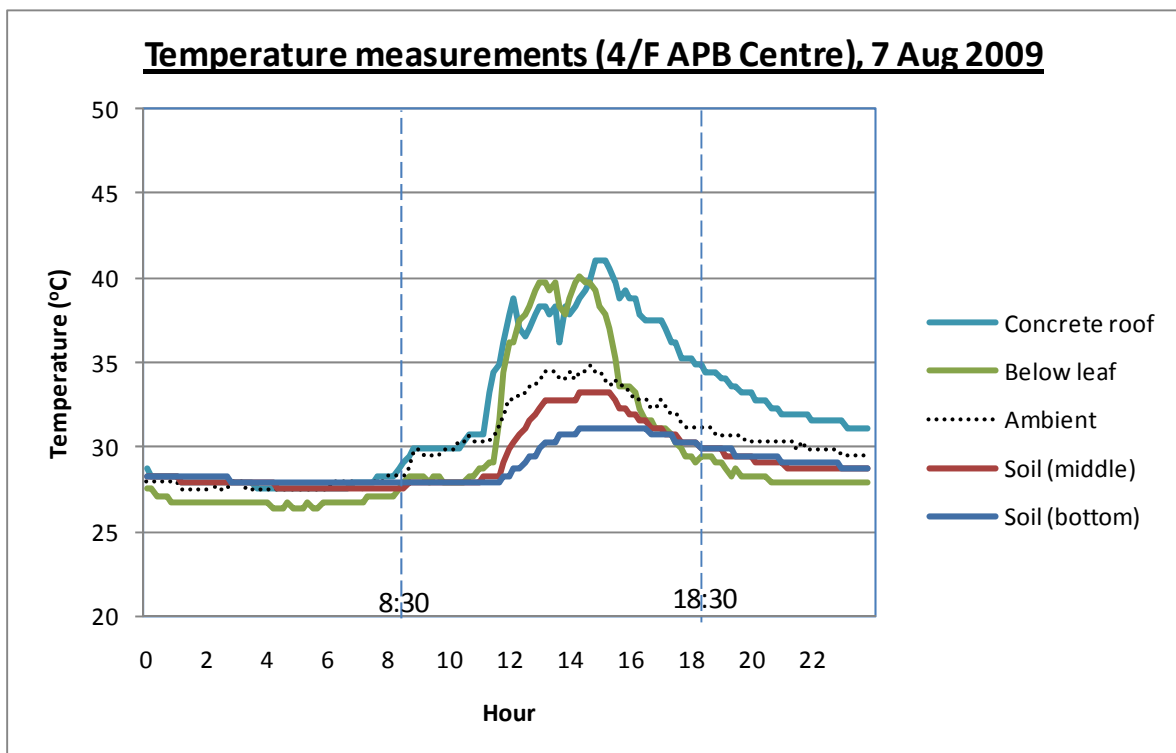


Figure A11.4 Temperature data of APB Centre 4/F, 7 Aug 2009

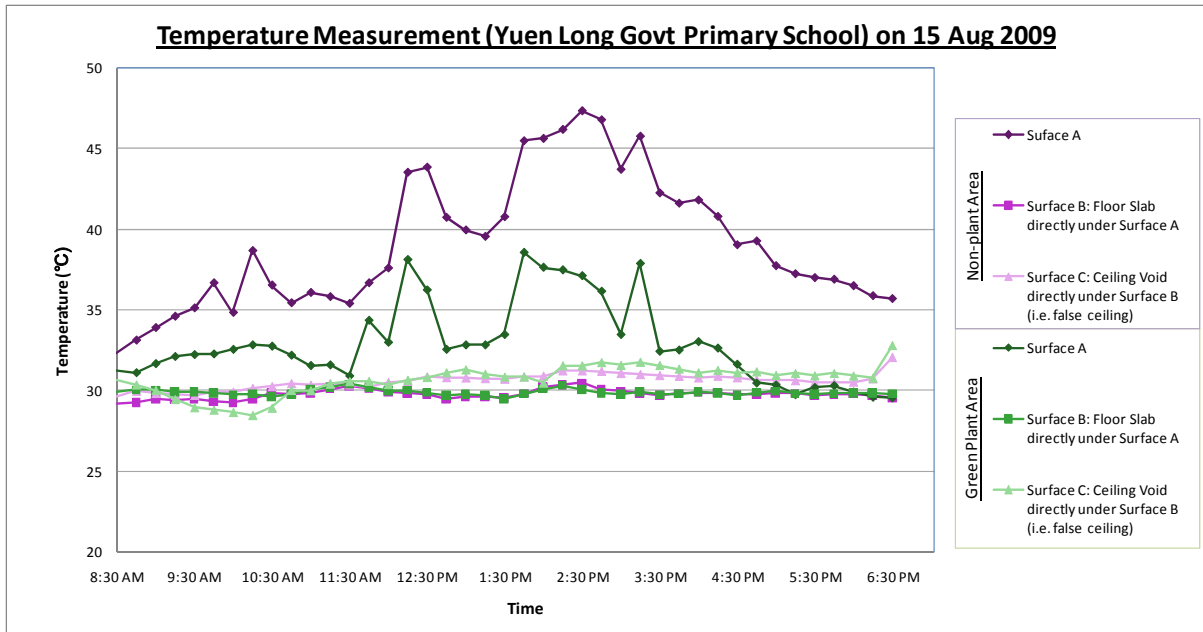


Figure A11.5 EMSD subcontractor's temperature data of YLGPS, 15 Aug 2009

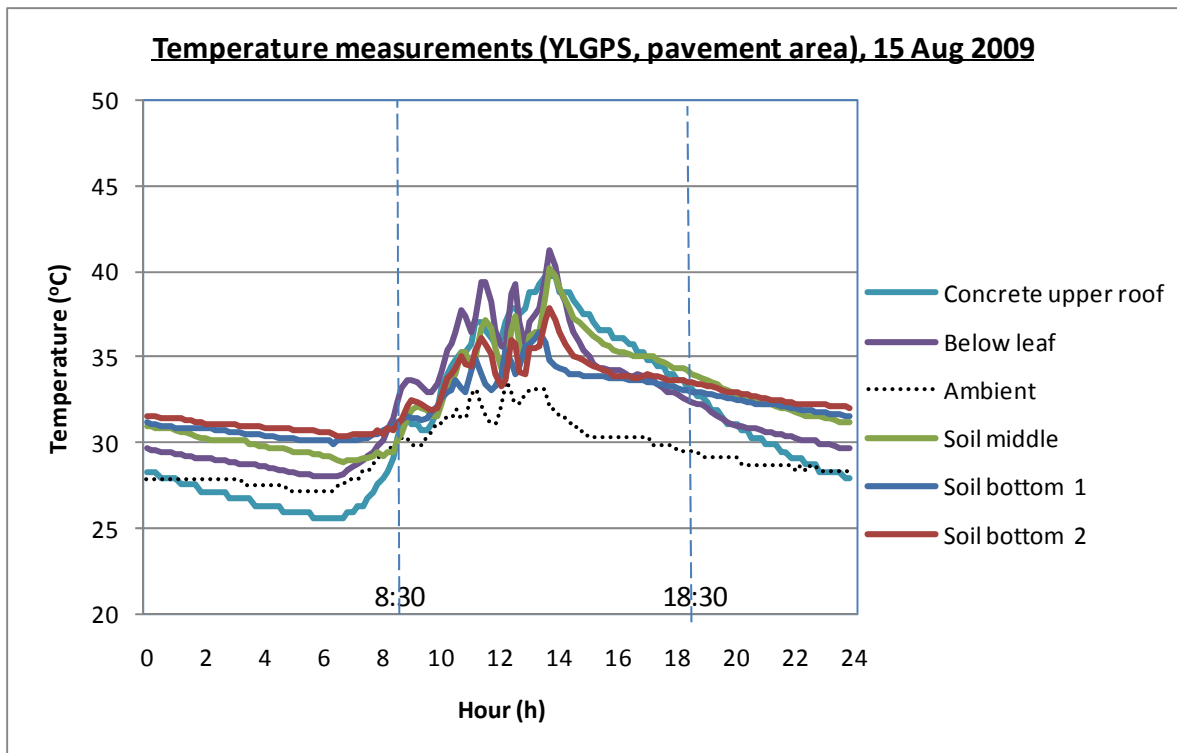


Figure A11.6 Temperature data of YLGPS (on pavement grass area), 15 Aug 2009

Appendix XII – U-value Calculations

Ngau Tau Kok Municipal Office Building – bare roof					
Ref	Layers of the building element	Thickness, d (m)	Density, ρ (kg/m ³)	Conduct., λ (W/m.K)	R = d/ λ (m ² .K/W)
	External surface air film				0.055
1	12 mm artificial granite tile	0.012	2650	2.9	0.004
2	50 mm top cement/sand screeding	0.05	1860	0.72	0.069
3	10 mm waterproofing membrane	0.01	1190	0.16	0.063
4	125 mm normal weight aggregate concrete	0.125	2400	2.16	0.058
	Internal surface air film				0.162
	TOTAL =	0.197			0.411
				U-value = $1 / \Sigma R$ (W/m ² K)	2.433

Note: Thermal properties of concrete is obtained from the Code of Practice for Overall Thermal Transfer Value in Building 1995.

Ngau Tau Kok Municipal Office Building – green roof 100 mm soil & short plants					
Ref	Layers of the building element	Thickness, d (m)	Density, ρ (kg/m ³)	Conduct., λ (W/m.K)	R = d/ λ (m ² .K/W)
	External surface air film				0.055
1	100 mm canopy plant layer	0.1	---	---	---
2	100 mm substrate/soil	0.1	1600	1.16	0.086
3	1 mm Atlantis geotextile filter fabric	0.001	---	0.3	0.003
4	30 mm Atlantis drainage cell	0.03	---	0.5	0.060
5	0.76 mm deeproot water barrier	0.00076	960	0.19	0.004
6	12 mm artificial granite tile	0.012	2650	2.9	0.004
7	50 mm top cement/sand screeding	0.05	1860	0.72	0.069
8	10 mm waterproofing membrane	0.01	1190	0.16	0.063
9	125 mm normal weight aggregate concrete	0.125	2400	2.16	0.058
	Internal surface air film				0.162
	TOTAL =	0.42876			0.564
				U-value = $1 / \Sigma R$ (W/m ² K)	1.772

Note: U-value of green roof includes the green roof plus the roof slab.

Ngau Tau Kok Municipal Office Building – green roof 150 mm soil & taller plants					
Ref	Layers of the building element	Thickness, d (m)	Density, ρ (kg/m ³)	Conduct., λ (W/m.K)	R = d/ λ (m ² .K/W)
	External surface air film				0.055
1	300 mm canopy plant layer	0.3	---	---	---
2	150 mm substrate/soil	0.15	1600	1.16	0.129
3	1 mm Atlantis geotextile filter fabric	0.001	---	0.3	0.003
4	30 mm Atlantis drainage cell	0.03	---	0.5	0.060
5	0.76 mm deeproot water barrier	0.00076	960	0.19	0.004
6	12 mm artificial granite tile	0.012	2650	2.9	0.004
7	50 mm top cement/sand screeding	0.05	1860	0.72	0.069
8	10 mm waterproofing membrane	0.01	1190	0.16	0.063
9	125 mm normal weight aggregate concrete	0.125	2400	2.16	0.058
	Internal surface air film				0.162
	TOTAL =	0.67876			0.608
				U-value = $1 / \Sigma R$ (W/m ² K)	1.646

Note: U-value of green roof includes the green roof plus the roof slab.

APB Centre, 4/F – bare roof						
Ref	Layers of the building element	Thickness, d (m)	Density, ρ (kg/m ³)	Conduct., λ (W/m.K)	R = d/λ (m ² .K/W)	
	External surface air film				0.055	
1	32 mm precast concrete tile	0.032	2100	1.1	0.029	
2	50 mm top cement/sand screeding	0.05	1860	0.72	0.069	
3	3 mm waterproofing membrane	0.003	1190	0.16	0.019	
4	50 mm cement/sand screeding	0.05	1860	0.72	0.069	
5	150 mm light weight aggregate concrete	0.15	1300	0.44	0.341	
6	150 mm normal weight aggregate concrete	0.15	2400	2.16	0.069	
	Internal surface air film				0.162	
TOTAL =		0.435			0.814	
					U-value = 1 / ΣR (W/m ² K)	1.228

APB Centre, 4/F – green roof						
Ref	Layers of the building element	Thickness, d (m)	Density, ρ (kg/m ³)	Conduct., λ (W/m.K)	R = d/λ (m ² .K/W)	
	External surface air film				0.055	
1	100 mm canopy plant layer	0.1	---	---	---	
2	100 mm substrate/soil	0.1	1600	1.16	0.086	
3	1 mm filter sheet	0.001	---	0.3	0.003	
4	25 mm drainage/storage layer FD25	0.025	---	0.5	0.050	
5	3 mm water retention mat	0.003	---	0.19	0.016	
6	2 mm root barrier	0.002	960	0.19	0.011	
7	32 mm precast concrete tile	0.032	2100	1.1	0.029	
8	50 mm top cement/sand screeding	0.05	1860	0.72	0.069	
9	3 mm waterproofing membrane	0.003	1190	0.16	0.019	
10	50 mm cement/sand screeding	0.05	1860	0.72	0.069	
11	150 mm light weight aggregate concrete	0.15	1300	0.44	0.341	
12	150 mm normal weight aggregate concrete	0.15	2400	2.16	0.069	
	Internal surface air film				0.162	
TOTAL =		0.666			0.980	
					U-value = 1 / ΣR (W/m ² K)	1.020

Note: U-value of green roof includes the green roof plus the roof slab.

APB Centre, 10/F – bare roof						
Ref	Layers of the building element	Thickness, d (m)	Density, ρ (kg/m ³)	Conduct., λ (W/m.K)	R = d/λ (m ² .K/W)	
	External surface air film				0.055	
1	32 mm precast concrete tile	0.032	2100	1.1	0.029	
2	50 mm top cement/sand screeding	0.05	1860	0.72	0.069	
3	3 mm waterproofing membrane	0.003	1190	0.16	0.019	
4	50 mm cement/sand screeding	0.05	1860	0.72	0.069	
5	150 mm light weight aggregate concrete	0.15	1300	0.44	0.341	
6	200 mm normal weight aggregate concrete	0.2	2400	2.16	0.093	
	Internal surface air film				0.162	
TOTAL =		0.485			0.837	
					U-value = 1 / ΣR (W/m ² K)	1.194

Note: U-value of green roof includes the green roof plus the roof slab.

APB Centre, 10/F – green roof					
Ref	Layers of the building element	Thickness, d (m)	Density, ρ (kg/m ³)	Conduct., λ (W/m.K)	R = d/λ (m ² .K/W)
	External surface air film				0.055
1	100 mm canopy plant layer	0.1	---	---	---
2	100 mm substrate/soil	0.1	1600	1.16	0.086
3	1 mm filter sheet	0.001	---	0.3	0.003
4	25 mm drainage/storage layer FD25	0.025	---	0.5	0.050
5	3 mm water retention mat	0.003	---	0.19	0.016
6	2 mm root barrier	0.002	960	0.19	0.011
7	32 mm precast concrete tile	0.032	2100	1.1	0.029
8	50 mm top cement/sand screeding	0.05	1860	0.72	0.069
9	3 mm waterproofing membrane	0.003	1190	0.16	0.019
10	50 mm cement/sand screeding	0.05	1860	0.72	0.069
11	150 mm light weight aggregate concrete	0.15	1300	0.44	0.341
12	200 mm normal weight aggregate concrete	0.2	2400	2.16	0.093
	Internal surface air film				0.162
	TOTAL =	0.716			1.003
				U-value = 1 / ΣR (W/m ² K)	0.997

Note: U-value of green roof includes the green roof plus the roof slab.

Yuen Long Government Primary School -- bare roof					
Ref	Layers of the building element	Thickness, d (m)	Density, ρ (kg/m ³)	Conduct., λ (W/m.K)	R = d/ λ (m ² .K/W)
	External surface air film				0.055
1	32 mm precast concrete tile	0.032	2100	1.1	0.029
2	50 mm top cement/sand screeding	0.05	1860	0.72	0.069
3	3 mm waterproofing membrane	0.003	1190	0.16	0.019
4	50 mm cement/sand screeding	0.05	1860	0.72	0.069
5	125 mm normal weight aggregate concrete	0.125	2400	2.16	0.058
	Internal surface air film				0.162
	TOTAL =	0.26			0.462
				U-value = 1 / ΣR (W/m ² K)	2.166

Yuen Long Government Primary School -- green roof, pavement area					
Ref	Layers of the building element	Thickness, d (m)	Density, ρ (kg/m ³)	Conduct., λ (W/m.K)	R = d/ λ (m ² .K/W)
	External surface air film				0.055
1	100 mm canopy plant layer	0.1	---	---	---
2	52 mm substrate/soil with Turf Cell permeable paving	0.052	1600	1.16	0.045
3	40 mm soil mixture	0.04	1600	1.16	0.034
4	10 mm sand	0.01	1600	1.16	0.009
5	1 mm Atlantis geotextile filter fabric	0.001	---	0.3	0.003
6	30 mm Atlantis drainage cell	0.03	---	0.5	0.060
7	0.76 mm deeproot water barrier	0.00076	960	0.19	0.004
8	50 mm top cement/sand screeding	0.05	1860	0.72	0.069
9	3 mm waterproofing membrane	0.003	1190	0.16	0.019
10	50 mm cement/sand screeding	0.05	1860	0.72	0.069
11	125 mm normal weight aggregate concrete	0.125	2400	2.16	0.058
	Internal surface air film				0.162
	TOTAL =	0.46176			0.588
				U-value = 1 / ΣR (W/m ² K)	1.701

Note: U-value of green roof includes the green roof plus the roof slab.

Yuen Long Government Primary School -- green roof, planter area					
Ref	Layers of the building element	Thickness, d (m)	Density, ρ (kg/m ³)	Conduct., λ (W/m.K)	R = d/ λ (m ² .K/W)
	External surface air film				0.055
1	500 mm canopy plant layer (average)	0.5	---	---	---
2	350 mm soil mixture	0.35	1600	1.16	0.302
3	1 mm Atlantis geotextile filter fabric	0.001	---	0.3	0.003
4	30 mm Atlantis drainage cell	0.03	---	0.5	0.060
5	0.76 mm deeproot water barrier	0.00076	960	0.19	0.004
6	50 mm top cement/sand screeding	0.05	1860	0.72	0.069
7	3 mm waterproofing membrane	0.003	1190	0.16	0.019
8	50 mm cement/sand screeding	0.05	1860	0.72	0.069
9	125 mm normal weight aggregate concrete	0.125	2400	2.16	0.058
	Internal surface air film				0.162
	TOTAL =	1.10976			0.802
				U-value = 1 / ΣR (W/m ² K)	1.248

Note: U-value of green roof includes the green roof plus the roof slab.

St. Bonaventure Catholic Primary School – bare roof					
Ref	Layers of the building element	Thickness, d (m)	Density, ρ (kg/m ³)	Conduct., λ (W/m.K)	R = d/λ (m ² .K/W)
	External surface air film				0.055
1	2 coats of decorated protective coating	0.002	---	---	---
2	20 mm mastic asphalt roofing	0.02	2330	1.15	0.017
3	5 mm black sheathing felt	0.005	960	0.19	0.026
4	25 mm cement/sand screeding	0.025	1860	0.72	0.035
5	125 mm normal weight aggregate concrete	0.125	2400	2.16	0.058
	Internal surface air film				0.162
	TOTAL =	0.177			0.353
				U-value = 1 / ΣR (W/m ² K)	2.830

St. Bonaventure Catholic Primary School – green roof (very light weight)					
Ref	Layers of the building element	Thickness, d (m)	Density, ρ (kg/m ³)	Conduct., λ (W/m.K)	R = d/λ (m ² .K/W)
	External surface air film				0.055
1	50 mm canopy plant layer	0.05	---	---	---
2	50 mm substrate/soil	0.1	1600	1.16	0.086
3	1 mm filter sheet	0.001	---	0.3	0.003
4	15 mm drainage layer	0.015	---	0.5	0.030
5	2 mm root barrier	0.002	960	0.19	0.011
1	2 coats of decorated protective coating	0.002	---	---	---
2	20 mm mastic asphalt roofing	0.02	2330	1.15	0.017
3	5 mm black sheathing felt	0.005	960	0.19	0.026
4	25 mm cement/sand screeding	0.025	1860	0.72	0.035
5	125 mm normal weight aggregate concrete	0.125	2400	2.16	0.058
	Internal surface air film				0.162
	TOTAL =	0.345			0.483
				U-value = 1 / ΣR (W/m ² K)	2.069

Note: U-value of green roof includes the green roof plus the roof slab.

St. Bonaventure Catholic Primary School – green roof (urban farming box on bare roof)					
Ref	Layers of the building element	Thickness, d (m)	Density, ρ (kg/m ³)	Conduct., λ (W/m.K)	R = d/λ (m ² .K/W)
	External surface air film				0.055
1	300 mm canopy plant layer	0.3	---	---	---
2	200 mm substrate/soil	0.2	1600	1.16	0.172
3	1 mm filter sheet	0.001	---	0.3	0.003
4	25 mm drainage/storage layer FD25	0.025	---	0.5	0.050
5	3 mm water retention mat	0.003	---	0.19	0.016
6	5 mm fibreglass box	0.005	---	0.05	0.100
8	2 coats of decorated protective coating	0.002	---	---	---
9	20 mm mastic asphalt roofing	0.02	2330	1.15	0.017
10	5 mm black sheathing felt	0.005	960	0.19	0.026
11	25 mm cement/sand screeding	0.025	1860	0.72	0.035
12	125 mm normal weight aggregate concrete	0.125	2400	2.16	0.058
	Internal surface air film				0.162
	TOTAL =	0.711			0.695
				U-value = 1 / ΣR (W/m ² K)	1.439

Note: U-value of green roof includes the green roof plus the roof slab.

St. Bonaventure Catholic Primary School – bare roof + fabric glass insulation panel					
Ref	Layers of the building element	Thickness, d (m)	Density, ρ (kg/m ³)	Conduct., λ (W/m.K)	R = d/λ (m ² .K/W)
	External surface air film				0.055
1	50 mm fibreglass insulation panel	0.05	---	0.05	1.000
2	2 coats of decorated protective coating	0.002	---	---	---
3	20 mm mastic asphalt roofing	0.02	2330	1.15	0.017
4	5 mm black sheathing felt	0.005	960	0.19	0.026
5	25 mm cement/sand screeding	0.025	1860	0.72	0.035
6	125 mm normal weight aggregate concrete	0.125	2400	2.16	0.058
	Internal surface air film				0.162
	TOTAL =	0.227			1.353
				U-value = 1 / ΣR (W/m ² K)	0.739

St. Bonaventure Catholic Primary School – green roof (urban farming box) + insulation panel					
Ref	Layers of the building element	Thickness, d (m)	Density, ρ (kg/m ³)	Conduct., λ (W/m.K)	R = d/λ (m ² .K/W)
	External surface air film				0.055
1	300 mm canopy plant layer	0.3	---	---	---
2	200 mm substrate/soil	0.2	1600	1.16	0.172
3	1 mm filter sheet	0.001	---	0.3	0.003
4	25 mm drainage/storage layer FD25	0.025	---	0.5	0.050
5	3 mm water retention mat	0.003	---	0.19	0.016
6	5 mm fibreglass box	0.005	---	0.05	0.100
7	50 mm fibreglass insulation panel	0.05	---	0.05	1.000
8	2 coats of decorated protective coating	0.002	---	---	---
9	20 mm mastic asphalt roofing	0.02	2330	1.15	0.017
10	5 mm black sheathing felt	0.005	960	0.19	0.026
11	25 mm cement/sand screeding	0.025	1860	0.72	0.035
12	125 mm normal weight aggregate concrete	0.125	2400	2.16	0.058
	Internal surface air film				0.162
	TOTAL =	0.761			1.695
				U-value = 1 / ΣR (W/m ² K)	0.590

Note: U-value of green roof includes the green roof plus the roof slab.

Appendix XIII – Building Energy Simulation Model and Results

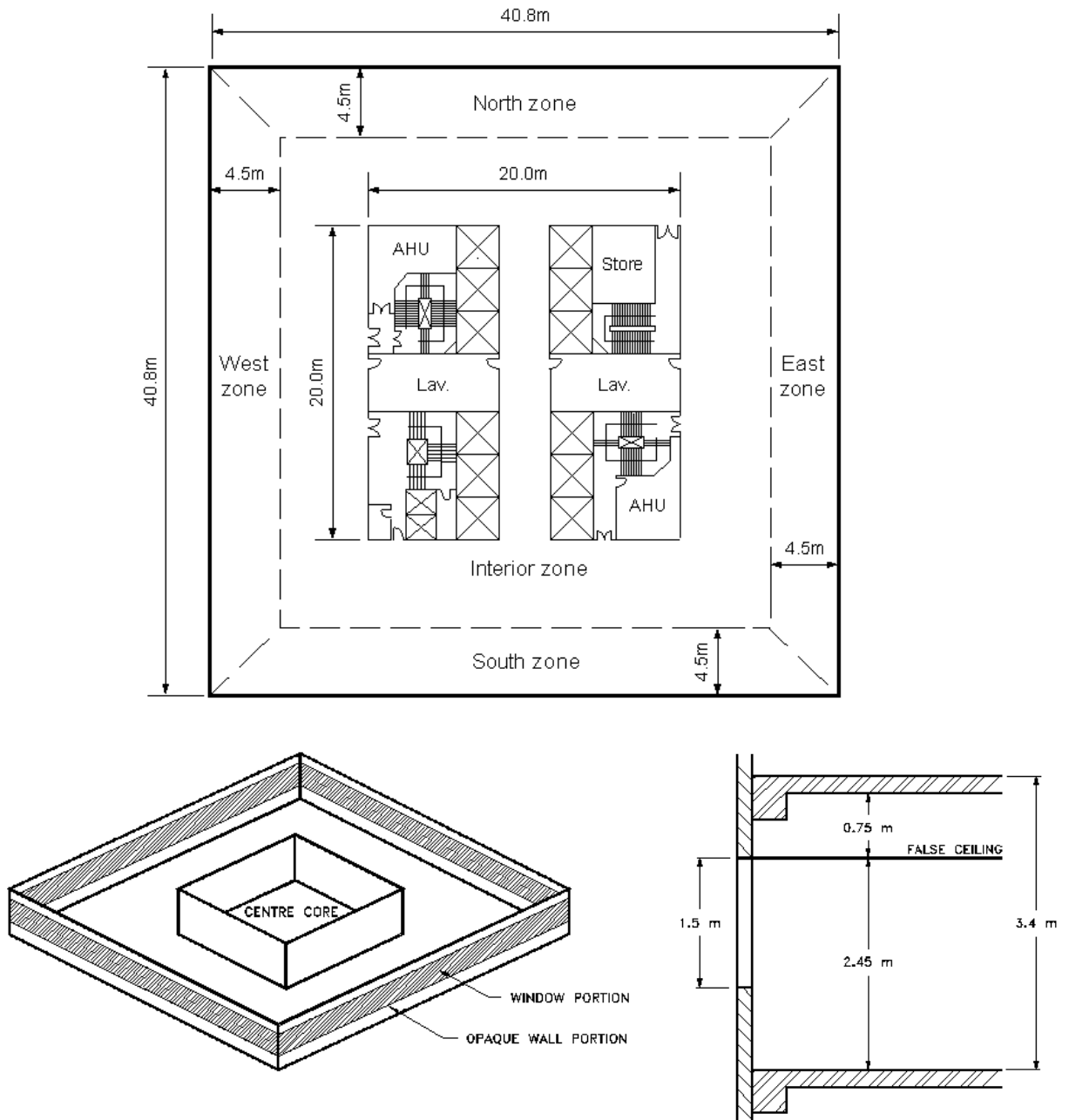


Figure A13.1 Typical floor of base case model office building

Summary of input data and key results from Energy-10:
 (For Reference Case and Reference Case w/o roof)
 (For one storey typical floor; assume roof U-value the same as NTK Building)

Energy-10 Summary Page

Dec 28, 2009

Project: Base Case Office Project Directory: C:/Program Files/Energy-10/Version 1.8/Projects/Office01

Description:	Reference Case	Reference Case (w/o roof)
Scheme Number:	5 / Saved	6 / Saved
Library Name:	ASHRAELIB	ASHRAELIB
Simulation status, Thermal/DL	valid/NA	valid/NA
Weather file:	hongkong.et1	hongkong.et1
Floor Area, m ²	1665.0	1665.0
Surface Area, m ²	3884.9	2219.9
Volume, m ³	5661.6	5661.6
Total Conduction UA, W/K	6249.0	2261.0
Average U-value, W/m ² K	1.609	1.019
Wall Construction	concrete wall, R=0.4	concrete wall, R=0.4
Roof Construction	r=0.411, R=0.4	r=0.411, R=0.4
Floor type, insulation	Slab on Grade, Reff=6.4	Slab on Grade, Reff=6.4
Window Construction	4060 single, alum, U=6.98	4060 single, alum, U=6.98
Window Shading	None	None
Wall total gross area, m ²	555	555
Roof total gross area, m ²	1665	0
Ground total gross area, m ²	1665	1665
Window total gross area, m ²	161	161
Windows (N/E/S/W:Roof)	18/18/18/18:0	18/18/18/18:0
Glazing name	single, U=6.30	single, U=6.30

Operating parameters for zone 1

	PTAC with ER Heat	PTAC with ER Heat
HVAC system	PTAC with ER Heat	PTAC with ER Heat
Rated Output (Heat/SCool/TCool), kW	100/284/378	52/176/235
Rated Air Flow/MOOA, L/s	17910/1416	9046/1416
Heating thermostat	21.0 ° C, no setback	21.0 ° C, no setback
Cooling thermostat	24.0 ° C, no setup	24.0 ° C, no setup
Heat/cool performance	eff=100, COP=2.4	eff=100, COP=2.4
Economizer?/type	no/NA	no/NA
Duct leaks/conduction losses, total %	0/0	0/0
Peak Gains: IL, EL, HW, OT: W/m ²	20.00/3.55/2.80/16.36	20.00/3.55/2.80/16.36
Added mass?	none	none
Daylighting?	no	no
Infiltration, cm ²	ELA=5125.3	ELA=5125.3

Results:

	0.000\$/GJ, 1.000\$/GJ, 0.000\$/kW	0.000\$/GJ, 1.000\$/GJ, 0.000\$/kW
Energy cost	0.000\$/GJ, 1.000\$/GJ, 0.000\$/kW	0.000\$/GJ, 1.000\$/GJ, 0.000\$/kW
Simulation dates	01-Jan to 31-Dec	01-Jan to 31-Dec
Energy use, kWh	599287	507842
Energy cost, \$	2156627	1827547
Saved by daylighting, GJ	-	NA
Total Electric (**), GJ	2157069	1827922
(** less Sellback, if any)		
Internal/External lights, GJ	364037/86987	364037/86987
Heating/Cooling/Fan, GJ	17126/1050692/42180	89/759334/21429
Hot water/Other, GJ	76579/519468	76579/519468
Peak Electric, kW	205.2	155.3
Fuel, hw/heat/total, kWh	0/0/0	0/0/0
Emissions, CO2/SO2/NOx, kg	365280/2147/1114	309542/1819/944
Construction Costs	2961652	2857583
Life-Cycle Cost	71568978	60941065

Table A13.1 Summary of building energy simulation results for one typical floor

Ref.	Description of roof construction	U-value (W/m ² .K)*	Total Elec. ('000 GJ)	Peak Elec. (kW)**
0	Reference case with bare roof	2.433	2157	205.2
	Reference case (w/o roof) (hypothetical, no roof load)	---	1828	155.3
1	NTK Building -- bare roof	2.433	2157	205.2
	NTK Building -- green roof 100 mm soil & short plants	1.772	1991	171.0
	NTK Building -- green roof 150 mm soil & taller plants	1.646	1982	169.3
2a	APB Centre, 4/F -- bare roof	1.228	2003	173.4
	APB Centre, 4/F -- green roof 100 mm soil & sedum plants	1.020	1969	167.0
2b	APB Centre, 10/F -- bare roof	1.194	1979	168.6
	APB Centre, 10/F -- green roof 100 mm soil & sedum plants	0.997	1952	164.3
3	YLGPS -- bare roof	2.166	2019	176.6
	YLGPS -- green roof, pavement area, 92 mm soil & grass	1.701	1988	170.3
	YLGPS -- green roof, planter area 350 mm soil & tall plants	1.248	1951	164.2
4	SBCPS -- bare roof	2.830	2057	184.4
	SBCPS -- green roof (very light weight) 50 mm soil	2.069	2013	175.3
4 i)	SBCPS -- green roof (urban farming box on bare roof)	1.439	1968	166.7
4 ii)	SBCPS -- bare roof + fabric glass insulation panel	0.739	1902	158.2
4 iii)	SBCPS -- green roof (urban farming box on insulation panel)	0.590	1885	156.8

Note: * Please refer to Appendix XII for details of the U-value calculations. Apply for whole roof area.

** Total Elec. = total annual electricity or energy consumption for the whole building;

Peak Elec. = peak electrical demand for the whole building (usually in July or August)

From the two reference cases (Ref. 0) in Table A13.1, the effect of roof thermal load can be found. The roof thermal load can be expressed as percentage of building total energy consumption and building total peak demand, respectively.

$$\% \text{ of roof to building total energy} = (2157 - 1828) / 2157 \times 100\% = \underline{\underline{15.3\%}}$$

$$\% \text{ of roof to building total peak demand} = (205.2 - 155.3) / 205.2 \times 100\% = \underline{\underline{24.3\%}}$$

The above figures represent the relative importance of roof thermal load for the topmost floor of the building. If the building has multiple storeys, then these percentage figures will decrease accordingly.

To study the characteristics of the roof thermal load for different roof-envelope ratio, data is extracted from the building energy simulation results and calculations are performed to estimate the roof-envelope ratio and % of roof load to total energy. A summary of the calculations is given in the followings.

Calculations for the effects of roof-envelope ratio and number of storeys on percentage of roof to building total energy:

For one typical floor:						
Roof area (sq.m) =	1665					Total Elec ('000 GJ)
Floor area (sq.m) =	1665					2157
Gross wall area (sq.m) =	555			Reference case =		1828
Total envelope area (sq.m) =	3885			Reference case (w/o roof) =		
Nos. of storeys	Envelope area (sq.m)	Roof-envelope ratio, RER	Inverse of RER	Total Elec ('000 GJ)	Roof load ('000 GJ)	% of roof load to total elec
1	3885	0.43	2.33	2157	329	15.3
2	4440	0.38	2.67	3985	329	8.3
3	4995	0.33	3.00	5813	329	5.7
4	5550	0.30	3.33	7641	329	4.3
5	6105	0.27	3.67	9469	329	3.5
6	6660	0.25	4.00	11297	329	2.9
7	7215	0.23	4.33	13125	329	2.5
8	7770	0.21	4.67	14953	329	2.2
9	8325	0.20	5.00	16780	329	2.0
10	8880	0.19	5.33	18608	329	1.8
11	9435	0.18	5.67	20436	329	1.6
12	9990	0.17	6.00	22264	329	1.5
13	10545	0.16	6.33	24092	329	1.4
14	11100	0.15	6.67	25920	329	1.3
15	11655	0.14	7.00	27748	329	1.2
16	12210	0.14	7.33	29576	329	1.1
17	12765	0.13	7.67	31404	329	1.0
18	13320	0.13	8.00	33232	329	1.0
19	13875	0.12	8.33	35060	329	0.9
20	14430	0.12	8.67	36888	329	0.9
21	14985	0.11	9.00	38716	329	0.9
22	15540	0.11	9.33	40543	329	0.8
23	16095	0.10	9.67	42371	329	0.8
24	16650	0.10	10.00	44199	329	0.7
25	17205	0.10	10.33	46027	329	0.7
26	17760	0.09	10.67	47855	329	0.7
27	18315	0.09	11.00	49683	329	0.7
28	18870	0.09	11.33	51511	329	0.6
29	19425	0.09	11.67	53339	329	0.6
30	19980	0.08	12.00	55167	329	0.6

Appendix XIV – Estimation on the Effects of Adding Green Roof

1. Rough estimation of the effects of green roofs for the four green roof sites:

		NTK Building	APB 4/F	APB 10/F	YLGPS	SBCPS
Total roof area	(m ²)	250	1000	2368	280	520
Green roof area	(m ²)	112	147	206	280	240
% of green roof area	(%)	44.8%	14.7%	8.7%	100%	46.2%
U-value of bare roof	(W/sqm.K)	2.433	1.228	1.194	2.166	2.83
Area of bare roof	(m ²)	138	853	2162	0	280
U-value of green roof (short plants)	(W/sqm.K)	1.772	1.02	0.997	1.701	2.069
Area of green roof (short plants)	(m ²)	75	147	206	140	240
U-value of green roof (taller plants)	(W/sqm.K)	1.646			1.248	
Area of green roof (taller plants)	(m ²)	37			140	
Weighted U-value for whole roof	(W/sqm.K)	2.118	1.197	1.177	1.475	2.479
%U change	(%)	-12.9%	-2.5%	-1.4%	-31.9%	-12.4%
Estimated E for bare roof (top floor)	('000 GJ)	324	1193	2819	356	691
Estimated E with green roof (top floor)	('000 GJ)	317	1191	2816	340	676
%E change (top floor)	(%)	-2.1%	-0.2%	-0.1%	-4.6%	-2.2%
%U change = Percentage change of the U-value (compared to the bare roof)						
%E change = Percentage change of E (compared to the bare roof)(for top floor only)						
Regression equation for annual total building elec energy use: (based on roof area 1665 sqm)						
E = 140.9 U + 1814.1						
Estimated E = E x (Total roof area) / 1665						

2. Estimation of the effects of adding green roof on overall roof U-value:

U-value of bare roof (W/sqm.K)	R-value of bare roof (sqm.K/W)	Effect of adding green roof to the bare roof				
		R(GR) = R-value of green roof (sqm.K/W)				
		R(GR) =	0.1	0.2	0.3	0.4
3	0.333	$\Sigma R =$	0.433	0.533	0.633	0.733
		$U = 1/\Sigma R =$	2.31	1.88	1.58	1.36
		%U change	-23.1%	-37.5%	-47.4%	-54.5%
2.5	0.400	$\Sigma R =$	0.500	0.600	0.700	0.800
		$U = 1/\Sigma R =$	2.00	1.67	1.43	1.25
		%U change	-20.0%	-33.3%	-42.9%	-50.0%
2	0.500	$\Sigma R =$	0.600	0.700	0.800	0.900
		$U = 1/\Sigma R =$	1.67	1.43	1.25	1.11
		%U change	-16.7%	-28.6%	-37.5%	-44.4%
1.5	0.667	$\Sigma R =$	0.767	0.867	0.967	1.067
		$U = 1/\Sigma R =$	1.30	1.15	1.03	0.94
		%U change	-13.0%	-23.1%	-31.0%	-37.5%
1	1.000	$\Sigma R =$	1.100	1.200	1.300	1.400
		$U = 1/\Sigma R =$	0.91	0.83	0.77	0.71
		%U change	-9.1%	-16.7%	-23.1%	-28.6%
0.5	2.000	$\Sigma R =$	2.100	2.200	2.300	2.400
		$U = 1/\Sigma R =$	0.48	0.45	0.43	0.42
		%U change	-4.8%	-9.1%	-13.0%	-16.7%
		R(GR) = R-value of green roof (sqm.K/W)				
		ΣR = Sum of R-values of bare roof and green roof (sqm.K/W)				
		$U = 1/\Sigma R$ = overall roof U-value (W/sqm.K)				
		%U change = Percentage change of the U-value (compared to the bare roof)				

3. Estimation of the effects of adding green roof on annual total building electrical energy use:

U-value of bare roof (W/sqm.K)	R-value of bare roof (sqm.K/W)	Effect of adding green roof to the bare roof				
		R(GR) = R-value of green roof (sqm.K/W)				
		R(GR) =	0.1	0.2	0.3	0.4
3	0.333	$\Sigma R =$	0.433	0.533	0.633	0.733
E ('000 GJ) = 2237		U = 1/ $\Sigma R =$	2.31	1.88	1.58	1.36
		E =	2139	2078	2037	2006
		%E change	-4.4%	-7.1%	-9.0%	-10.3%
2.5	0.400	$\Sigma R =$	0.500	0.600	0.700	0.800
E ('000 GJ) = 2166		U = 1/ $\Sigma R =$	2.00	1.67	1.43	1.25
		E =	2096	2049	2015	1990
		%E change	-3.3%	-5.4%	-7.0%	-8.1%
2	0.500	$\Sigma R =$	0.600	0.700	0.800	0.900
E ('000 GJ) = 2096		U = 1/ $\Sigma R =$	1.67	1.43	1.25	1.11
		E =	2049	2015	1990	1971
		%E change	-2.2%	-3.8%	-5.0%	-6.0%
1.5	0.667	$\Sigma R =$	0.767	0.867	0.967	1.067
E ('000 GJ) = 2025		U = 1/ $\Sigma R =$	1.30	1.15	1.03	0.94
		E =	1998	1977	1960	1946
		%E change	-1.4%	-2.4%	-3.2%	-3.9%
1	1.000	$\Sigma R =$	1.100	1.200	1.300	1.400
E ('000 GJ) = 1955		U = 1/ $\Sigma R =$	0.91	0.83	0.77	0.71
		E =	1942	1932	1922	1915
		%E change	-0.7%	-1.2%	-1.7%	-2.1%
0.5	2.000	$\Sigma R =$	2.100	2.200	2.300	2.400
E ('000 GJ) = 1885		U = 1/ $\Sigma R =$	0.48	0.45	0.43	0.42
		E =	1881	1878	1875	1873
		%E change	-0.2%	-0.3%	-0.5%	-0.6%
R(GR) = R-value of green roof (sqm.K/W)						
ΣR = Sum of R-values of bare roof and green roof (sqm.K/W)						
U = 1/ ΣR = overall roof U-value (W/sqm.K)						
E = annual total building elec energy use ('000 GJ)						
%E change = Percentage change of E (compared to the bare roof)						
Regression equation for annual total building elec energy use:						
E = 140.9 U + 1814.1						