

Measurements in CoolTek House

(Low Energy House, Melaka, Malaysia)



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July-August 2006

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Introduction to measurements

The CoolTek ventilation concept is to rely on a solar chimney to pull air out of the building and pull fresh air through ground cooled pipes.

During my visit to the CoolTek house I became sceptical as to whether the solar chimney would be strong enough to exhaust air during the day time. My fear was, that the cool and 'heavy' air-conditioned indoor air instead would 'drop' out of the openings in the floor.

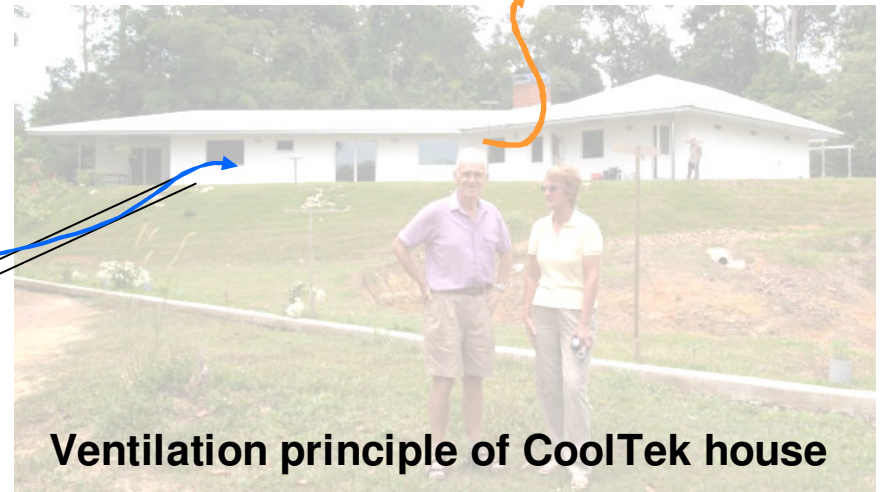
I was granted permission to evaluate the performance of the house through the use of measuring equipment. The results are presented here.

Original ventilation design intent:

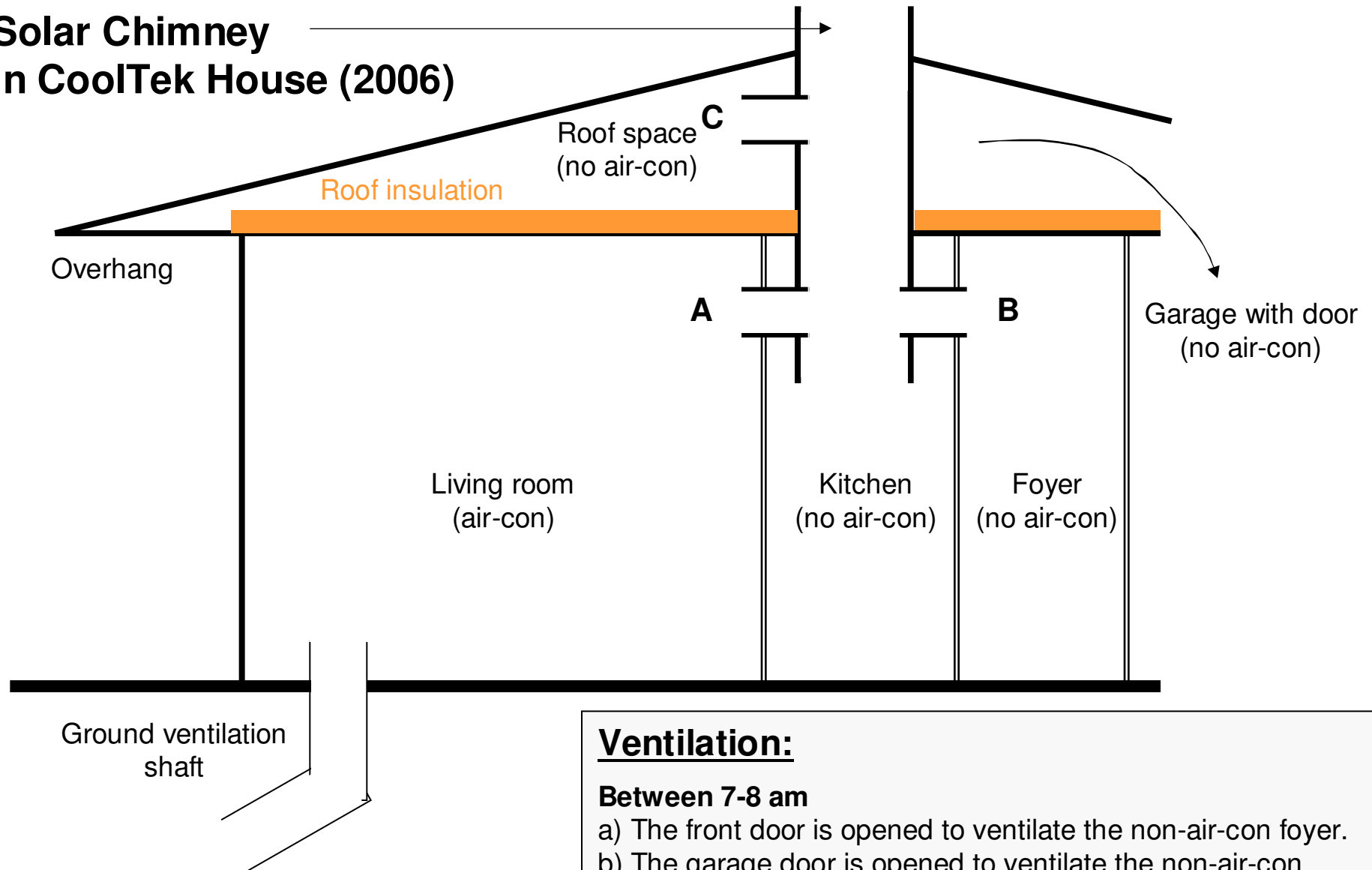
To provide cooler air mainly during any unoccupied period of the house, when [...] the air conditioning was switched off. A 'sealed' insulated and unventilated COOLTEK designed house without the air conditioning running would just keep getting hotter

Fresh air pulled through ground cooled pipe by solar chimney

Indoor air exhausted by solar chimney



Solar Chimney in CoolTek House (2006)



Solar chimney openings

- A:** Ventilation opening to living room
- B:** Ventilation opening to foyer
- C:** Ventilation opening to roof space

Ventilation:

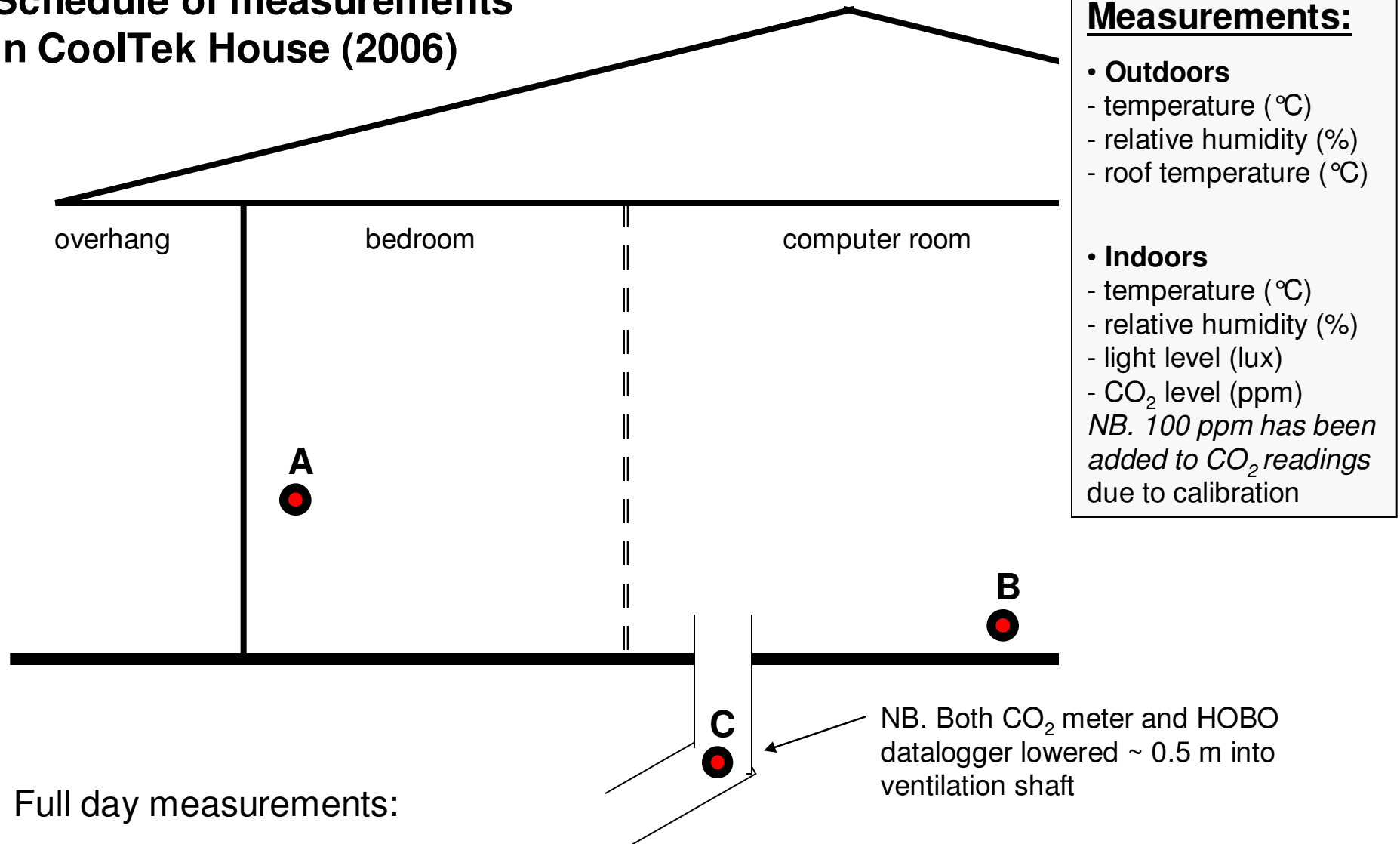
Between 7-8 am

- a) The front door is opened to ventilate the non-air-con foyer.
- b) The garage door is opened to ventilate the non-air-con garage; the roof space is connected with the garage

The rest of the day:

All windows and doors are closed, but garage door and roof space may not be very air tight and risk short circuiting solar chimney pull of indoor air.

Schedule of measurements in CoolTek House (2006)

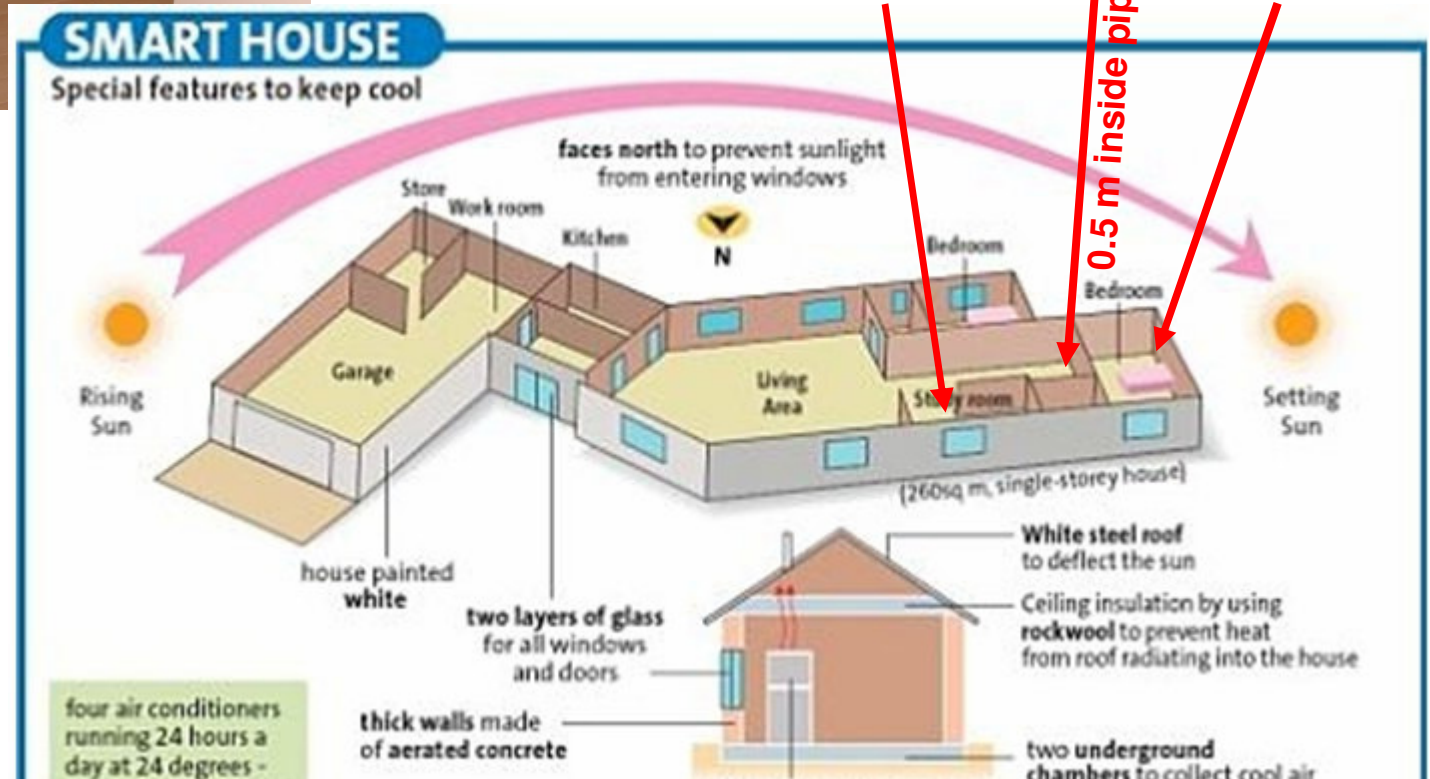
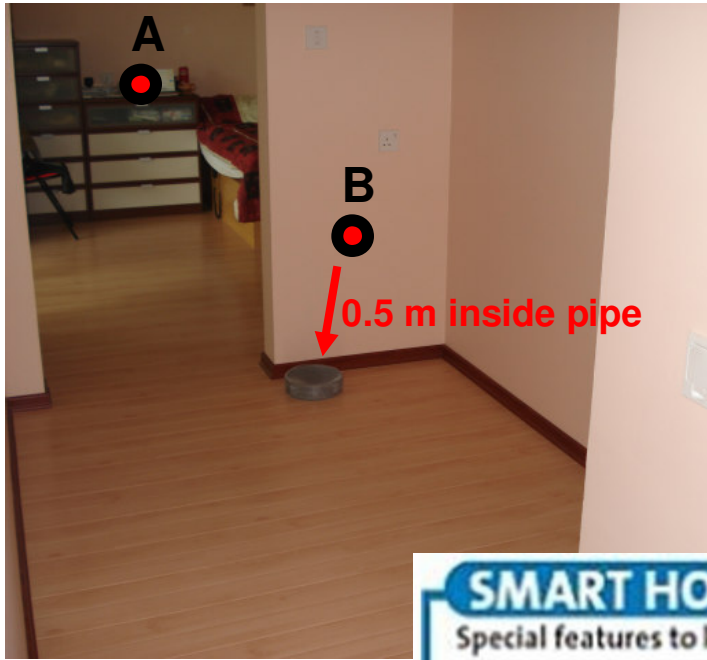


Full day measurements:

- **A:** 3 July – 15 July (Average electric house consumption: 20.4 kWh/day)
- **B:** 17 July – 29 July (Average electric house consumption: 20.1 kWh/day)
- **C:** 31 July – 12 August (Average electric house consumption: 19.1 kWh/day)

Equipment positioning

(No partitions between locations A, B and C)



Equipment

- HOBO (H08-004-02)
 - Temperature
 - Humidity

NB. Also datalogger



HOBO

- Telaire 7001
 - CO₂



Telaire 7001

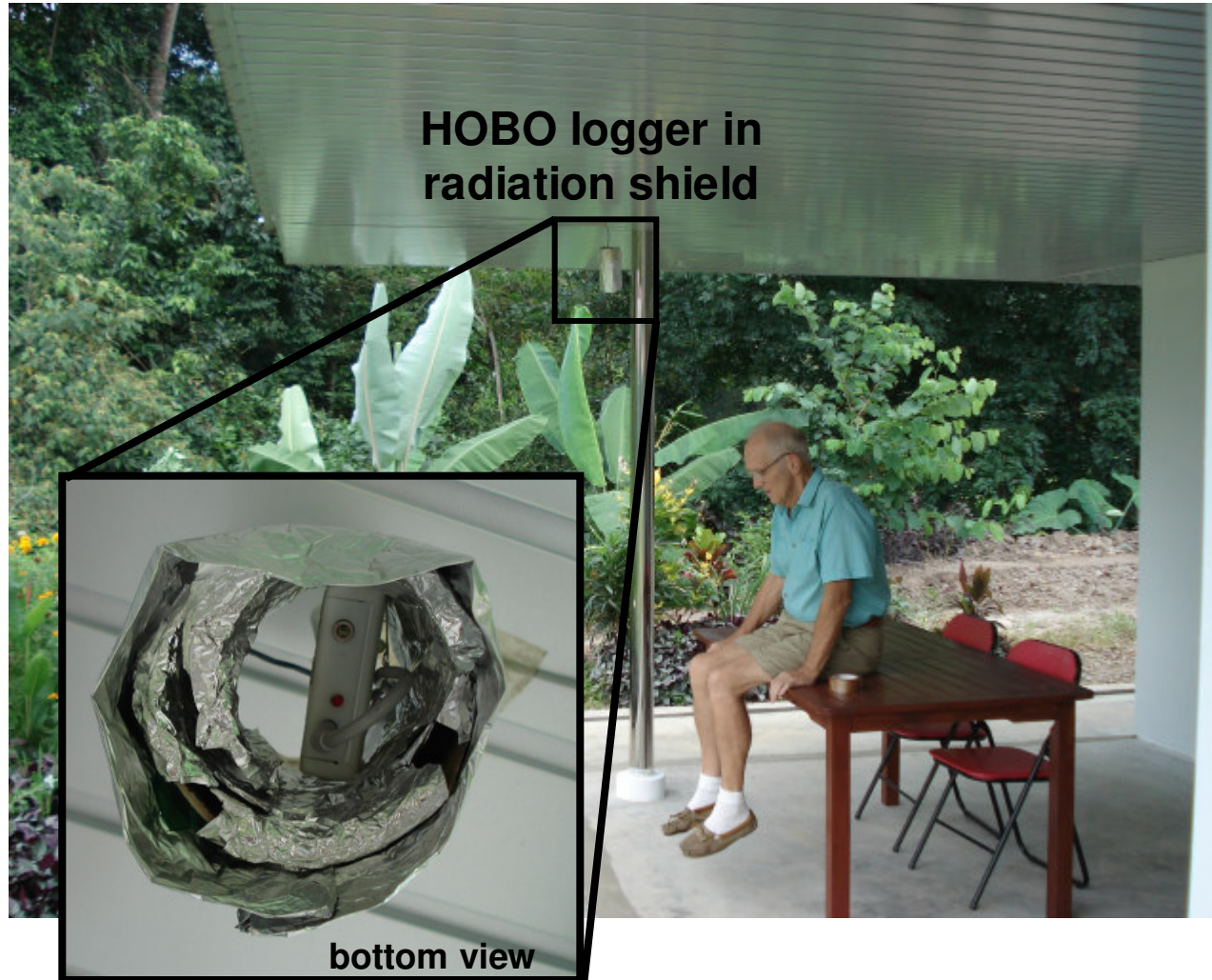
Logging interval:

- every 30 minutes
- 2nd July – 13 August 2006



External
temperature
cable
(TMC6-HB)

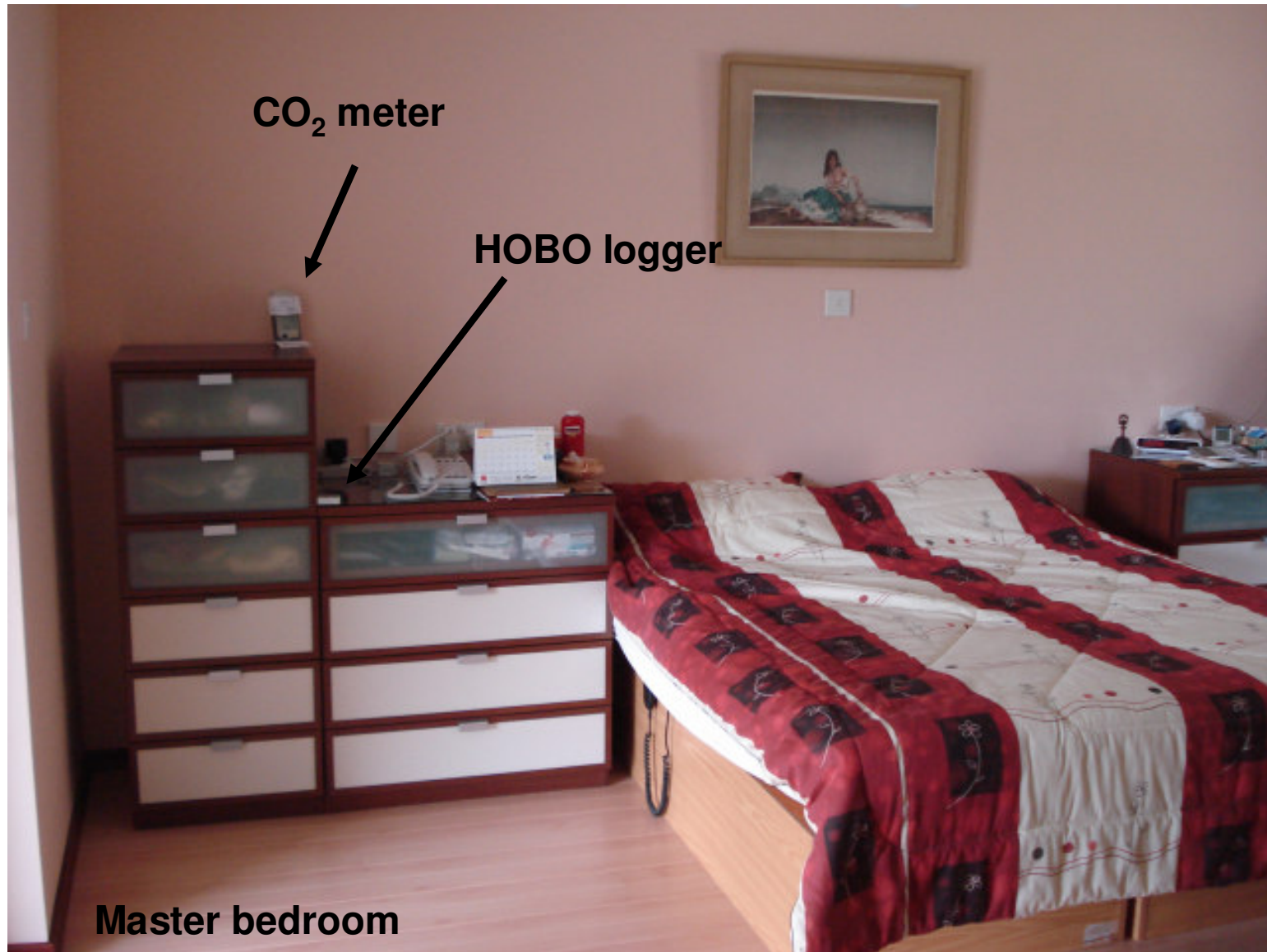
Outdoor Equipment Placement



Sensor to measure roof temperature

Indoor Equipment

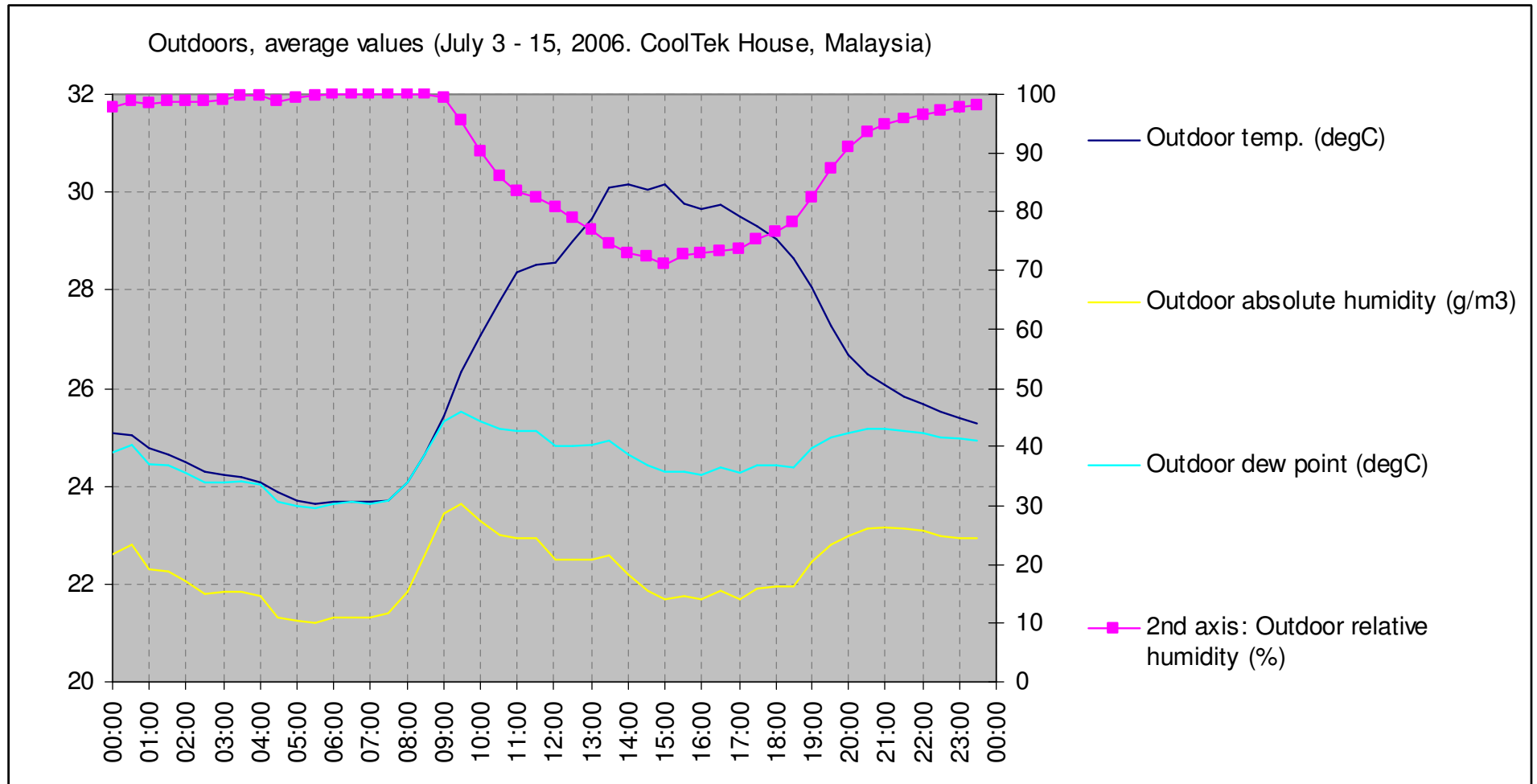
(was moved between 3 locations)



Data Analysis

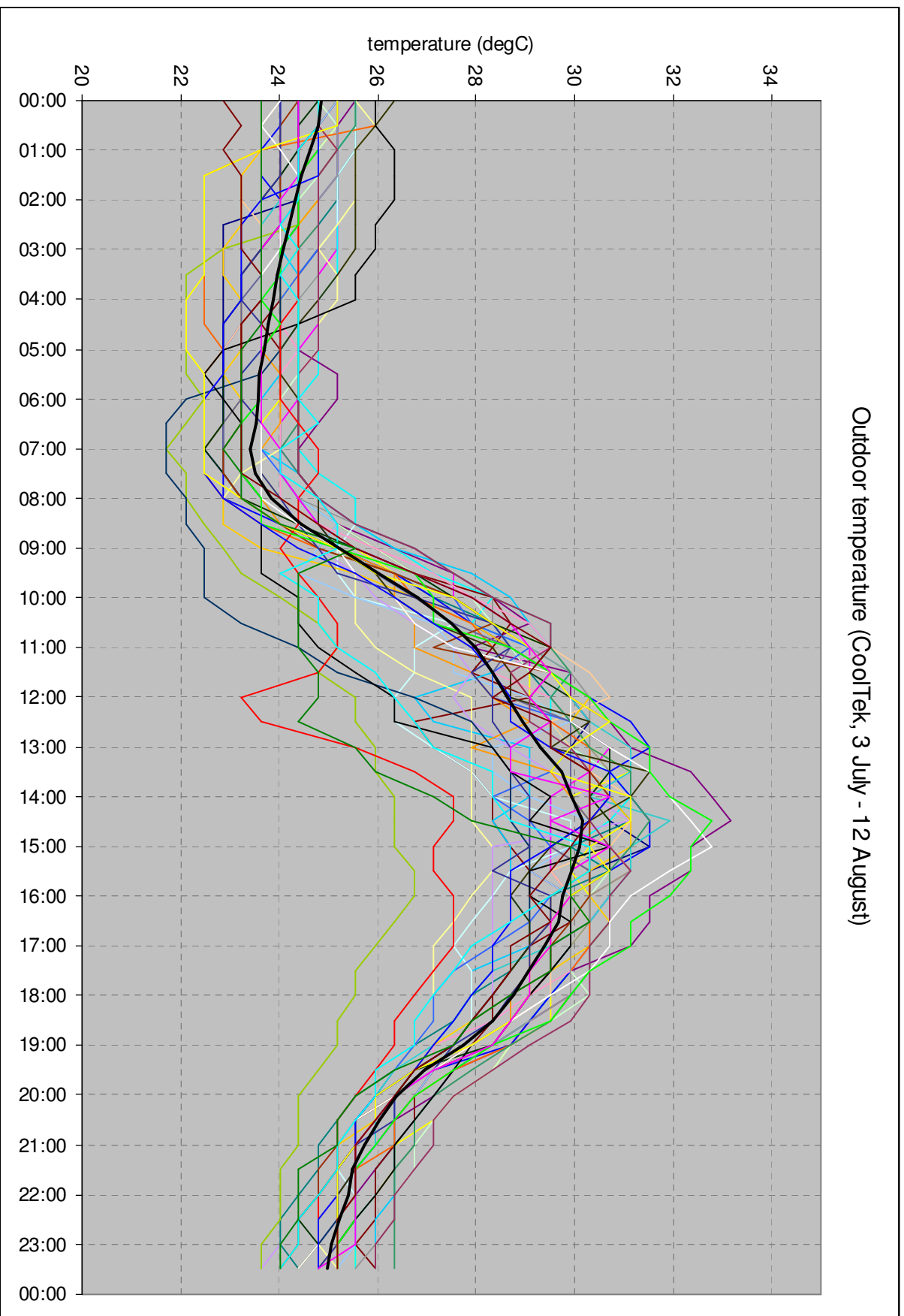
- 13 full day measurements (24 hour) obtained at each of the 3 locations:
A (Bedroom)
B (Computer room)
C (Floor ventilation)
- 30 minute logging intervals
- Average values for 13-day periods are used for comparisons
- House energy consumption varied max. 7% between the 3 datalogging periods
- Outdoor CO₂ level measured to 315 ppm
- During power failures no CO₂ readings were obtained. To fill the gap, the last measured value was used for the entire period. Power failures occurred about 5 times and always lasted less than 3 hours.

Outdoor Conditions

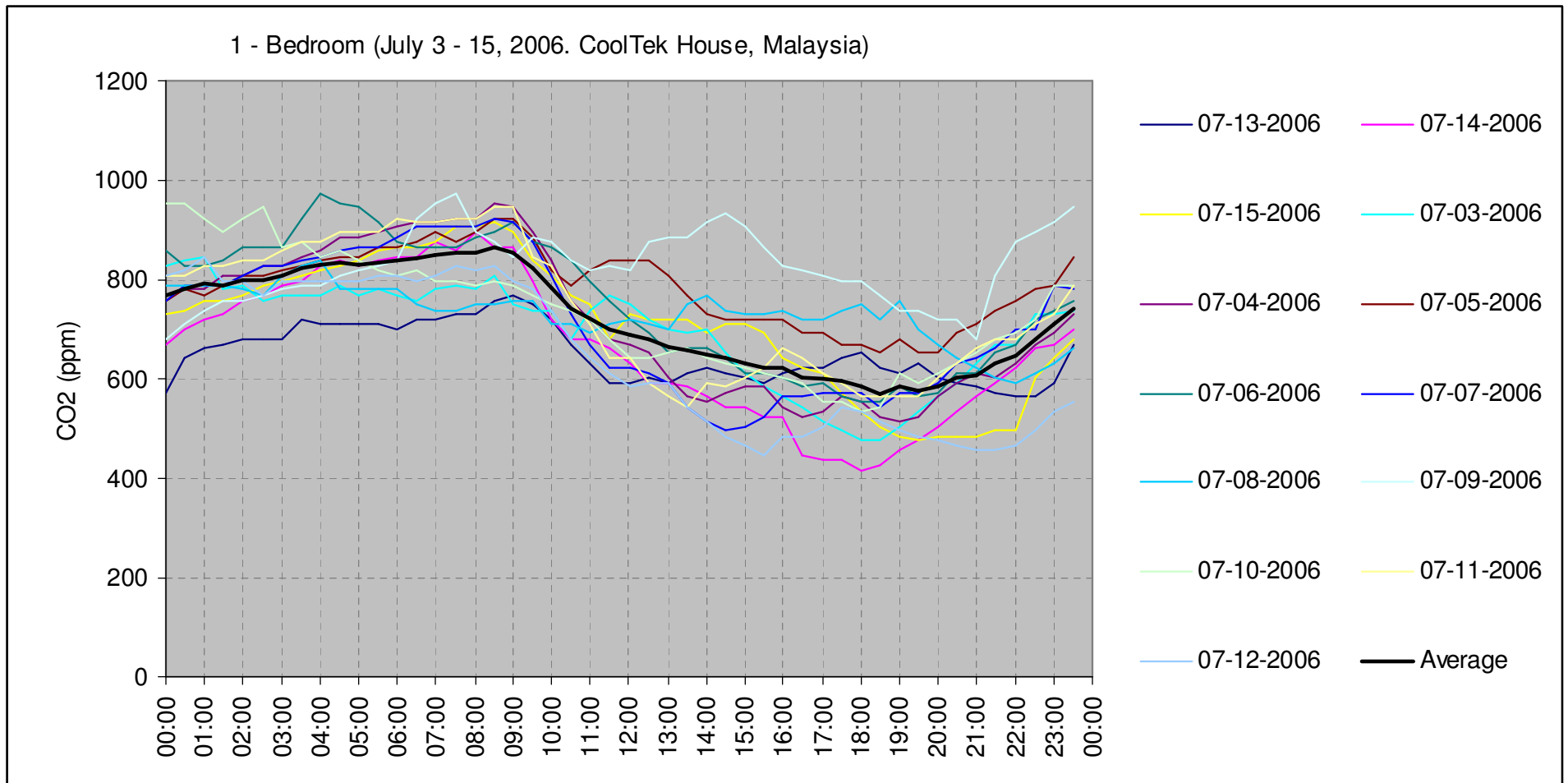


Outdoor Temperature

Outdoor temperature (CoolTek, 3 July - 12 August)

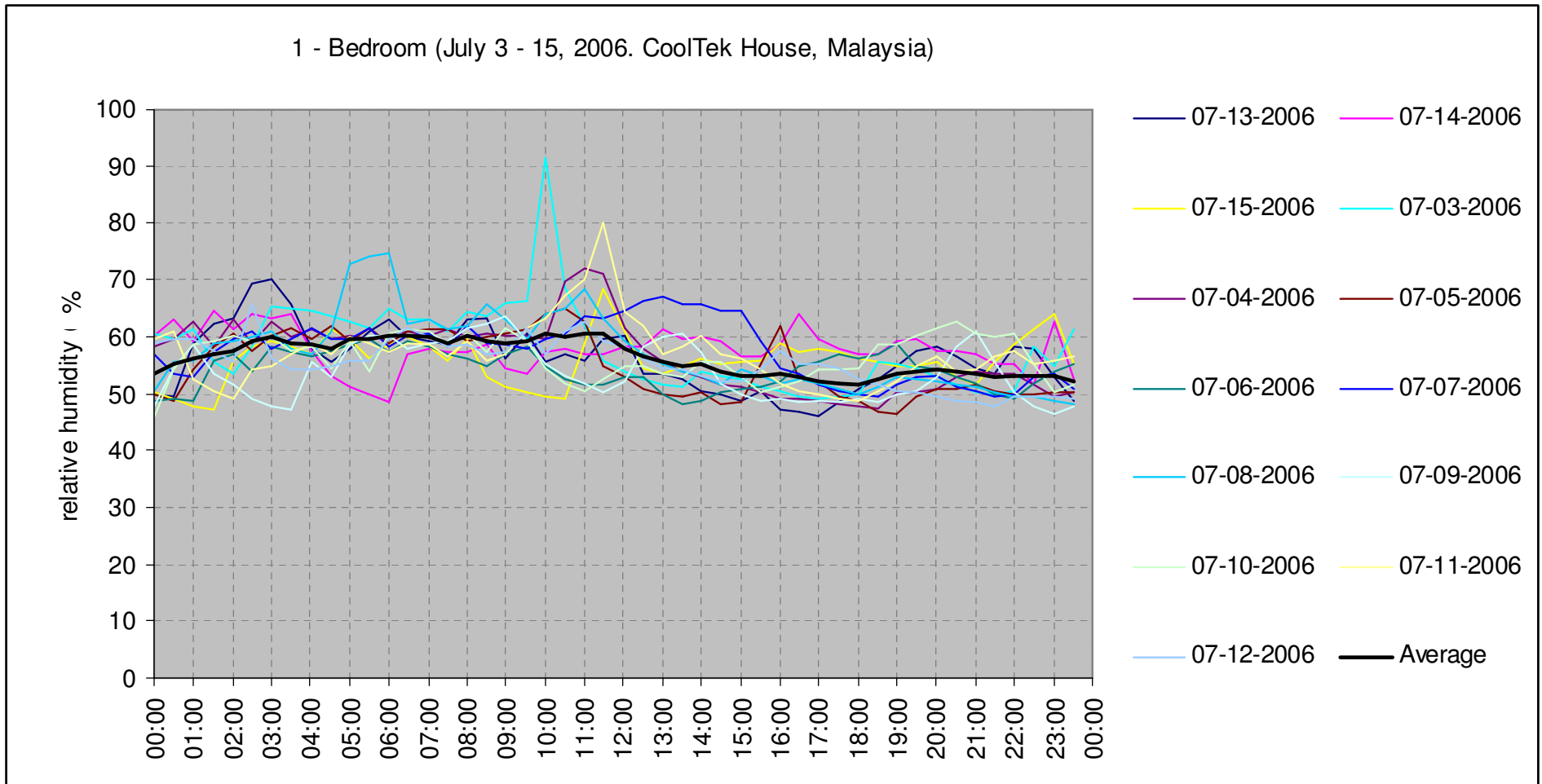


Indoor: CO₂ level



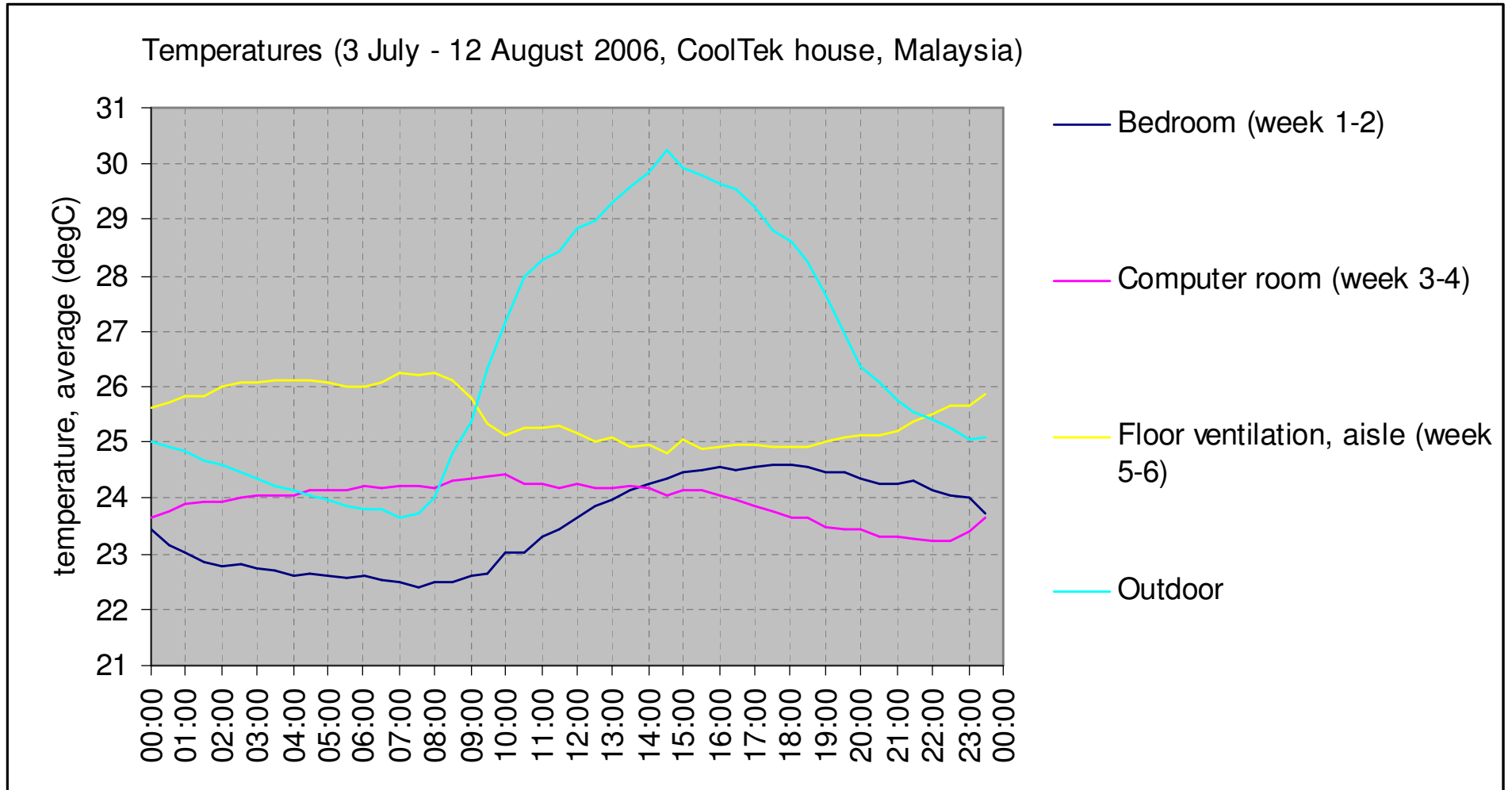
Average measurement shown with bold curve

Indoor: Relative humidity

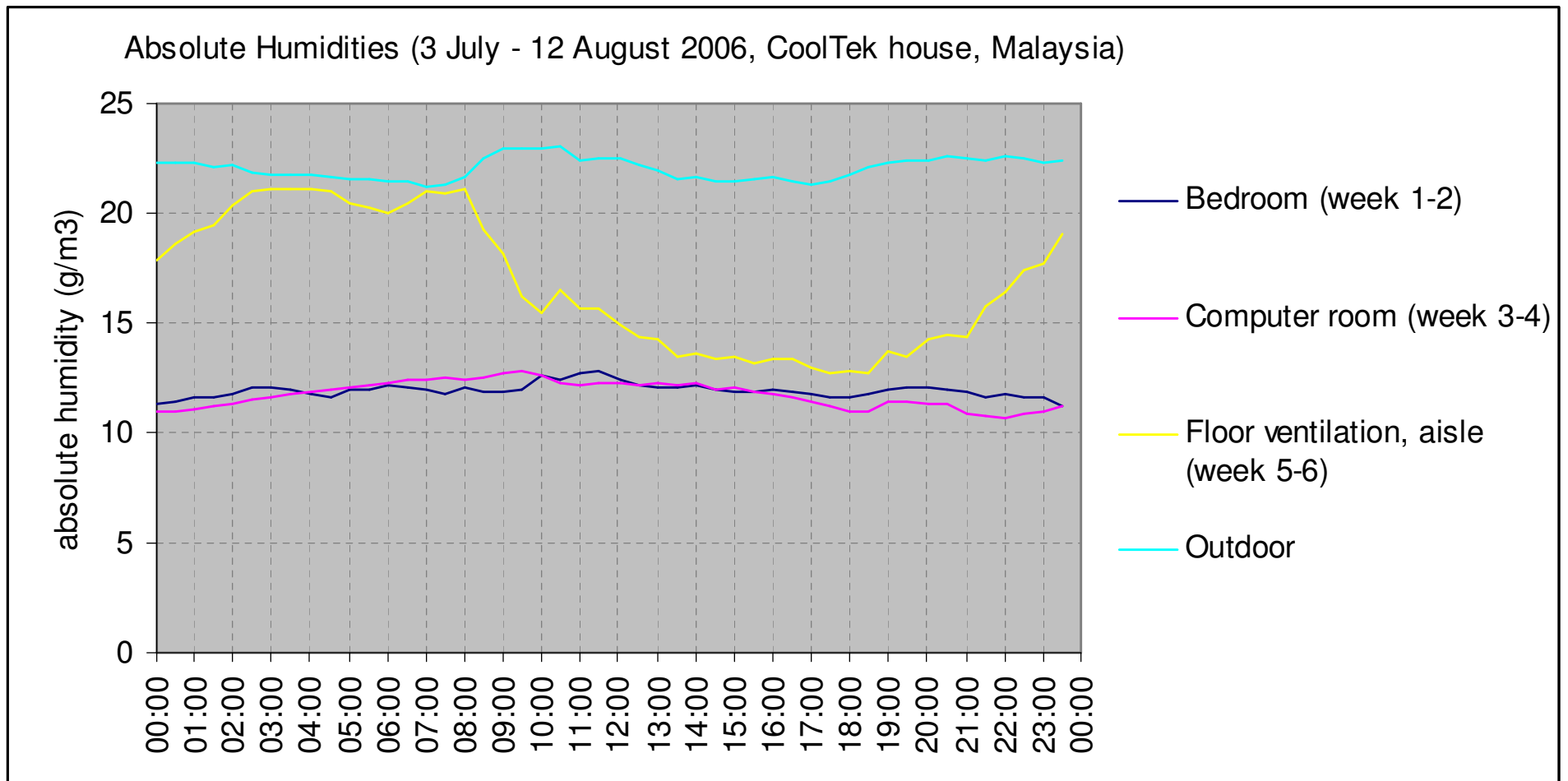


Comment: Peaks could be explained by rain and/or opening of door to patio

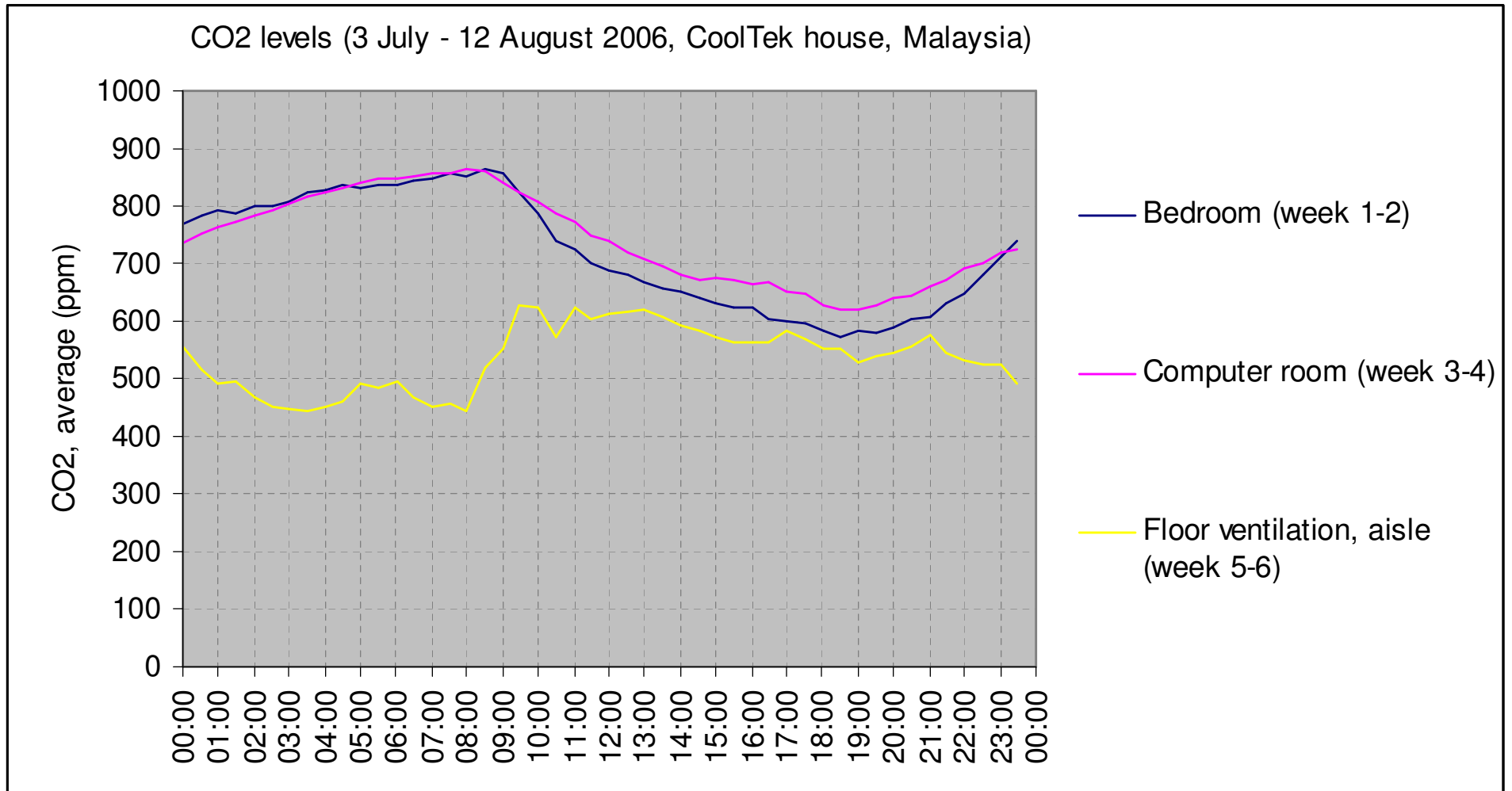
Comparison: Temperature



Comparison: Absolute Humidity



Comparison: CO₂

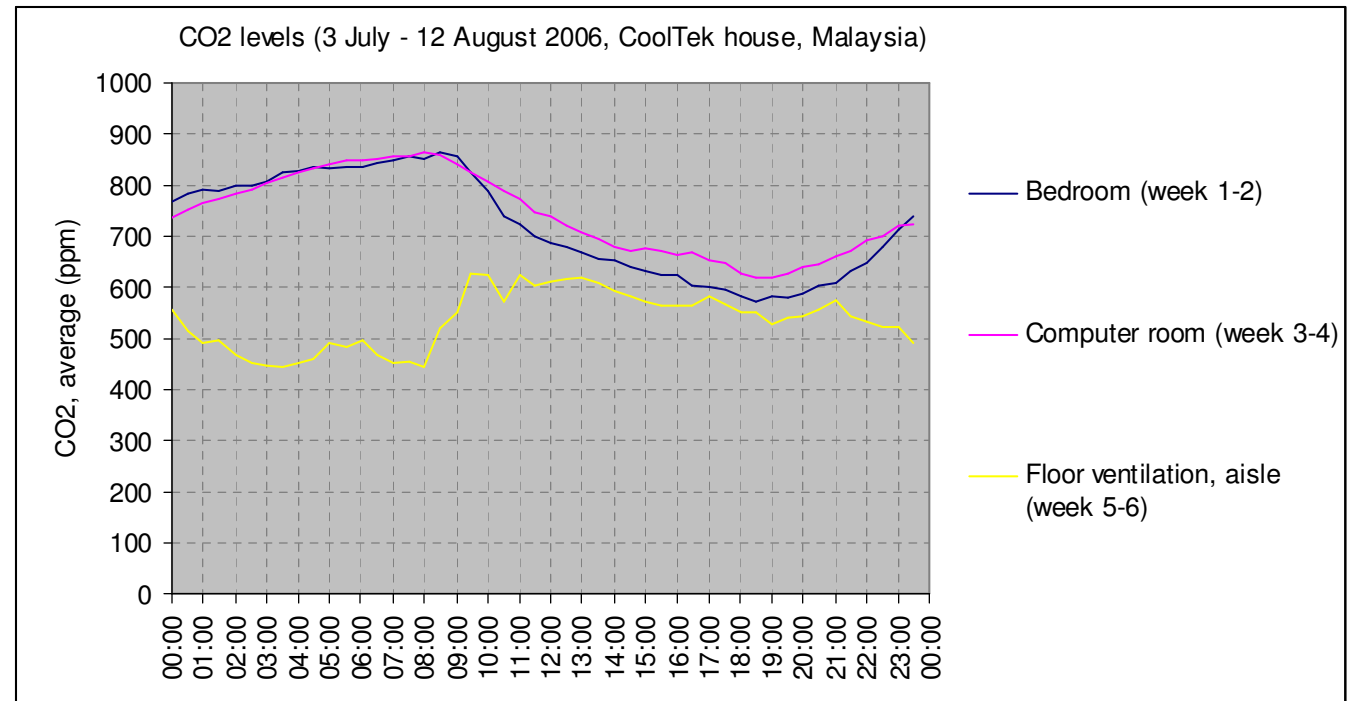
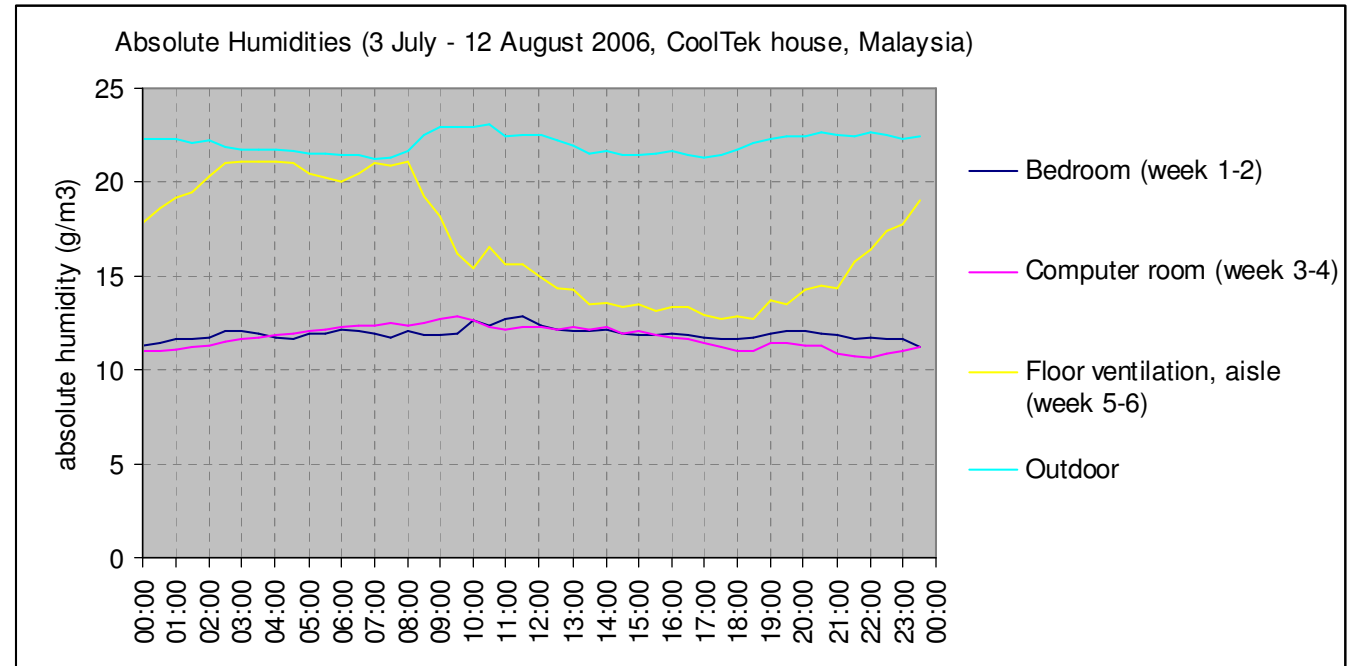


Analysis 1

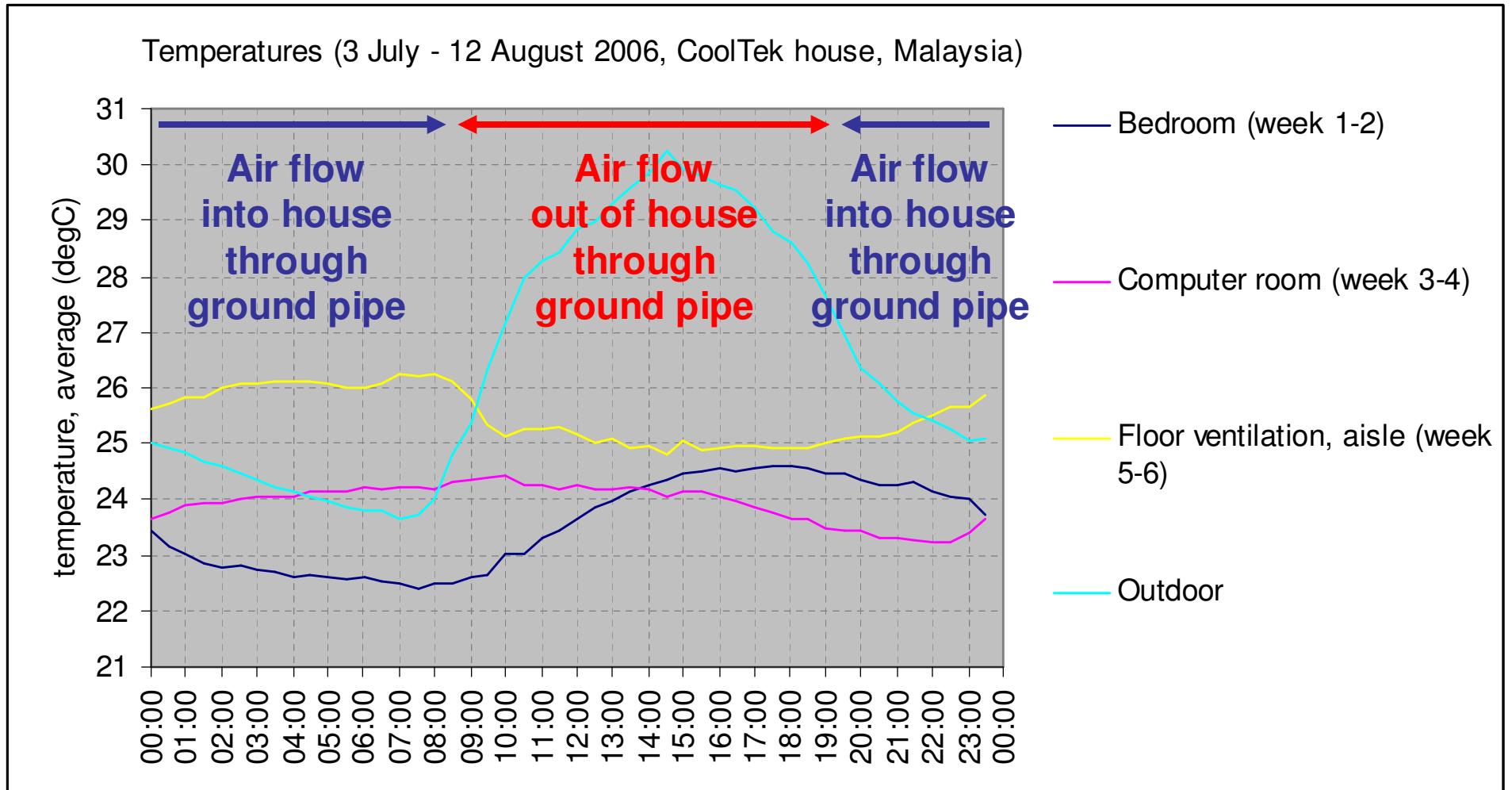
Both graphs indicate that:

- At night, air is pulled through the ground pipe from outdoors to indoors
- In the day, air 'drops' through the ground pipe from indoors to outdoors

For example, the absolute humidity in the floor ventilation is almost identical to the outdoor level at night and almost identical to the indoor level in the day time. The air flow direction changes at about 8:30 hours and at about 19:00 hours.

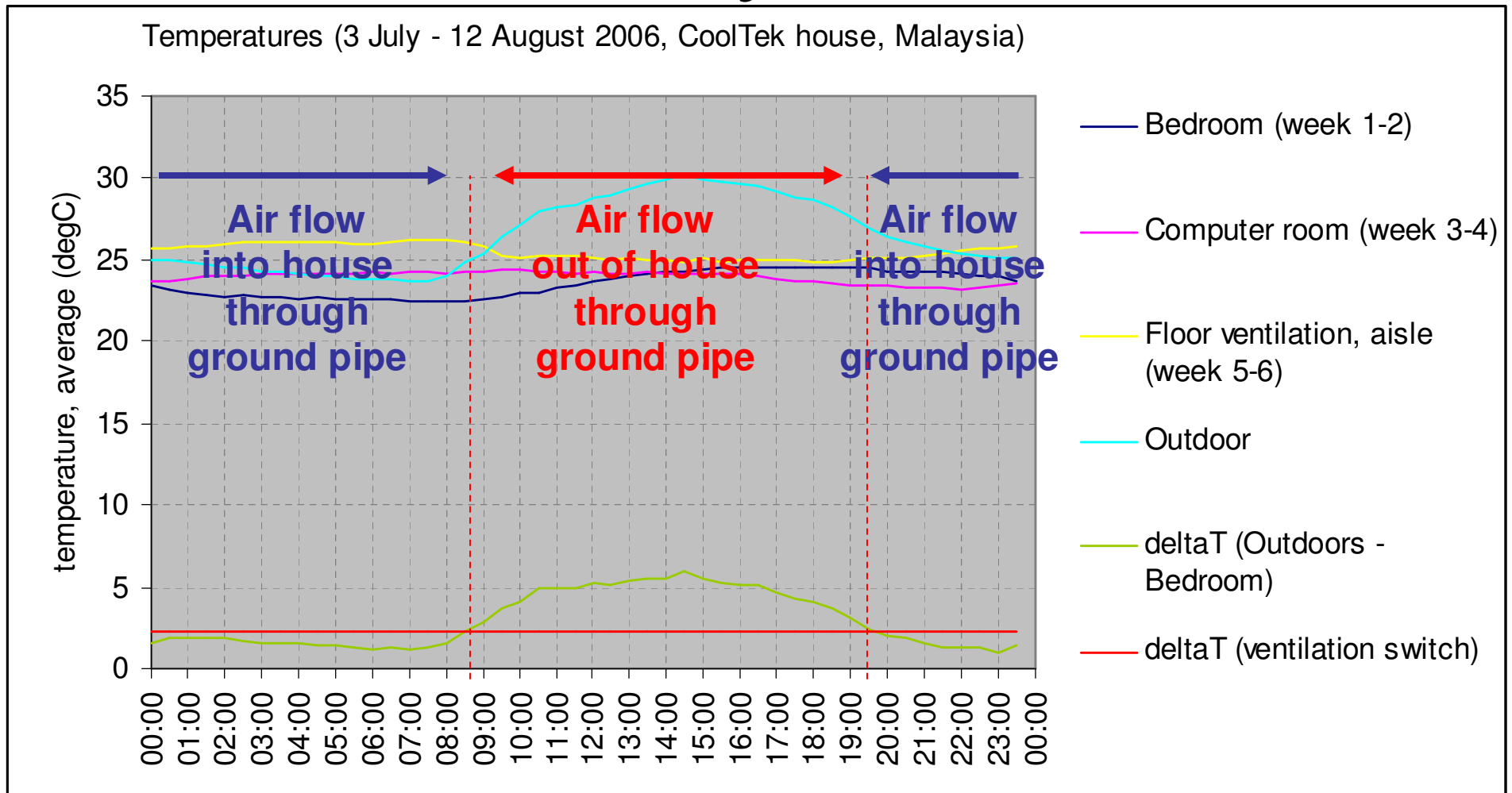


Analysis 2



Outside air enters the house through the ground cooled ventilation pipe at night (19:00 – 8:30). During this time it would be better to allow the outdoor air to enter through the windows, because the ground cooled ventilation pipe heats up the air by ~ 2 degC.

Analysis 3



When the temperature difference (deltaT) between the Outdoors and the Bedroom exceeds about 2 degC, then the thermal buoyancy force of the solar chimney is not sufficiently strong counteract the buoyancy force of the cooler and 'heavier' room air, which starts to 'drop' out of the floor pipes to the outdoors. NB. The insufficient pulling power of the solar chimney could also be partially caused by a short circuiting of air from garage and roof space.

Conclusions: General

6 weeks of datalogging of temperature, humidity and CO₂ level was undertaken for 3 different locations in the CoolTek house for 2 weeks at each location. The findings were:

- In the day time, the flow in the ground cooled ventilation pipes is reverse (from indoors to outdoors).
- At night, cool outdoor air is heated about 2 degC in the ground cooled ventilation pipe before entering the house.
- When the house is occupied, the design of the ground cooled ventilation pipe does not work as intended and does not add to the energy efficiency of the house.
- Simple improvements to system are possible (see recommendations)

Conclusions: Air Flow Direction

- The solar chimney is not strong enough to pull air through the ground pipe ventilation system – perhaps partially due to short circuiting of air from garage and roof space
- When the temperature of the outdoor air exceeds the indoor temperature by more than 2 degC, the flow in the ground cooled pipe ventilation is reverse (from indoors to outdoors)
- The reverse air flow (from indoors to outdoors) typically occurs between 8:30 hours and 19:00 hours
- At night the outdoor air is cooler than the air coming through the ground cooled ventilation pipe, hence, it would be an advantage to by-pass the ground cooled ventilation pipe at night and instead provide supply fresh air straight through the windows.

NB. Potential adverse effects by using windows for direct night ventilation is entry of noise, dust and horizontal rain. Entry of mosquitoes and lizards can be solved by netting, as is done for the ground cooled ventilation pipes

Conclusions: Indoor Climate

- The indoor climate is very stable
- The hourly average temperature in the bedroom fell within a narrow range of 22.5 – 24.5 degC. In the computer room the range was 23.5 – 24.5 degC.
- The hourly average relative humidity was stable in the range of 50 - 60%
- The CO₂ level in the bedroom and computer room were similar with peak levels of 800-900 ppm in the morning (9:00) and with the lowest levels of around 600 ppm occurring at night (19:00). The relatively high and relatively stable CO₂ levels (~ 600 ppm above outdoor levels) indicate that the house is very air-tight and has a sufficient ventilation level; it is recommended to stay below 1000 ppm to keep the perceived air quality acceptable.

NB. If a family of 4-5 people lived in the house the maximum recommended 1000 ppm CO₂ level would almost certainly be exceeded from time to time. It would pose no danger, but would just mean a decrease in perceived air quality.

Conclusions: Outdoor climate

- The average highest and lowest outdoor temperatures were 30.1 degC and 23.4 degC, respectively.
- The absolute max. and min. temperatures were 33.2 degC and 21.7 degC, respectively.
- The absolute humidity is stable around the clock at around 22 g/m³ with a small peak in the hours after sun rise.

Conclusions:

Ground + Roof temperatures

- Judging from the measured temperature in the ground cooling ventilation pipe, the ground temperature is around 26.3 degC. For comparison, the average outdoor temperature was measured to 26.35 degC. Often these two temperatures are equal.
- The temperature of the white metal sheet roof was measured (at the edge) at maximum 43.0 degC, and minimum at 20.2 degC. At night the roof is typically 1.5 degC lower than the outdoor temperature, which can be explained with radiation to the night sky. See graph in appendix.

Conclusions: Energy

- The house is 24-hour air-conditioned throughout the living space (24 degC and 55% relative humidity)
- The daily energy consumption is about 20 kWh inclusive of everything. This gives a monthly consumption of about 600 kWh, or RM 160 pr. month, or RM 5.30 pr. day.

Recommendation 1

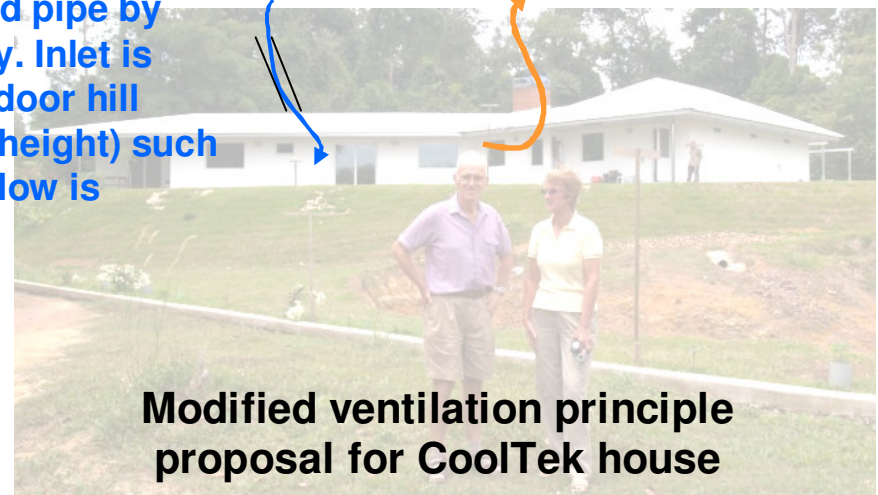
- Improvement of the ground cooled ventilation pipe:
 - a) Install a fan that can provide forced ventilation through ground cooled ventilation pipe in the day time.
 - b) The fan can either be installed in the ground cooled ventilation pipe or in solar chimney; the latter solution requires an air tight construction.
 - c) By-pass ground cooled ventilation pipe at night

Recommendation 2

- Preventing reverse flow in ground cooled ventilation pipes:
 - a) Install damper
or
 - b) Place inlet of ground cooled ventilation pipe above room level (see sketch); convection and levelling of partial moisture pressures will still take place, but the reverse flow will be partially halted.

Fresh air sucked through ground cooled pipe by solar chimney. Inlet is placed in outdoor hill (above room height) such that reverse flow is prevented

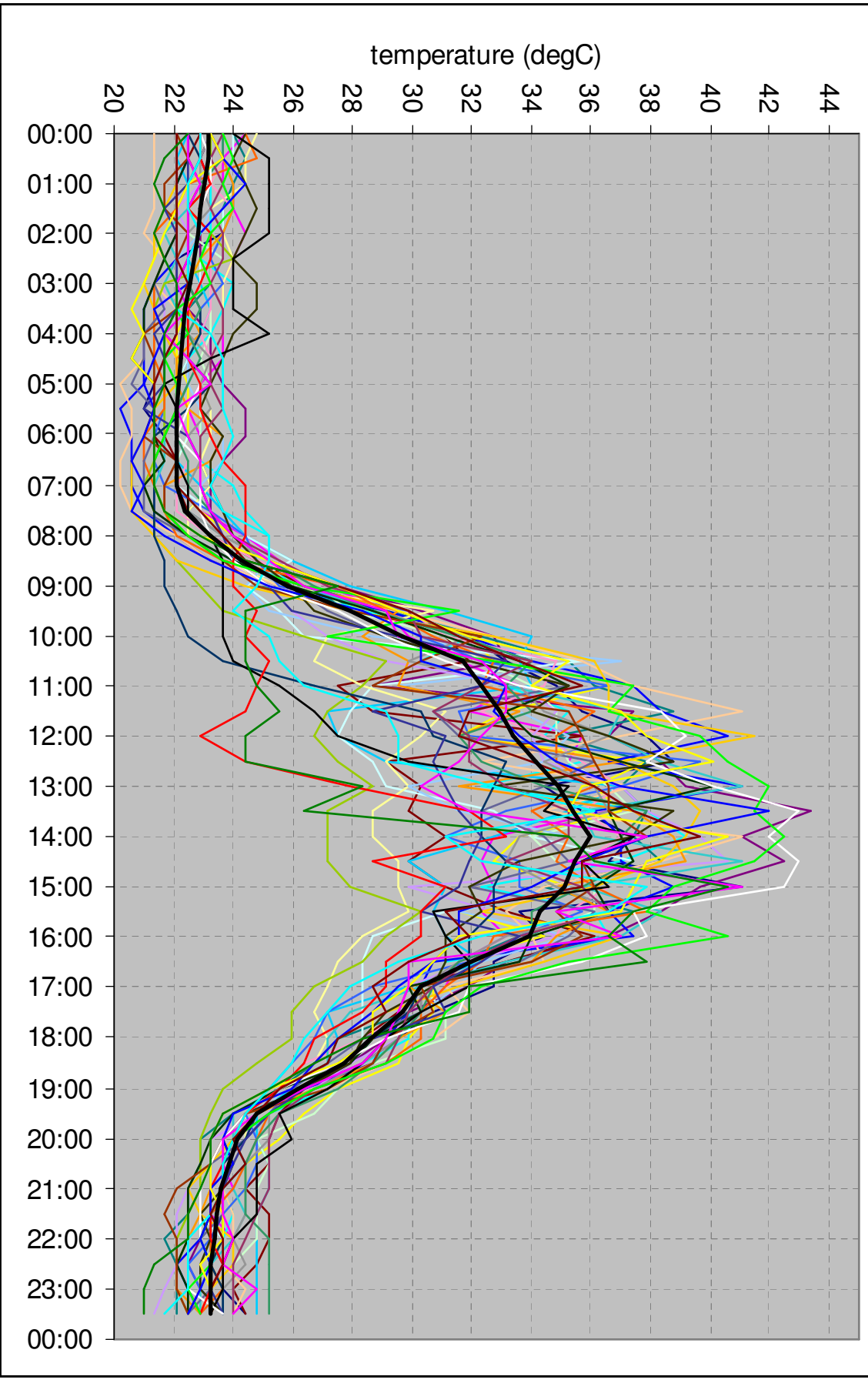
Indoor air exhausted by solar chimney



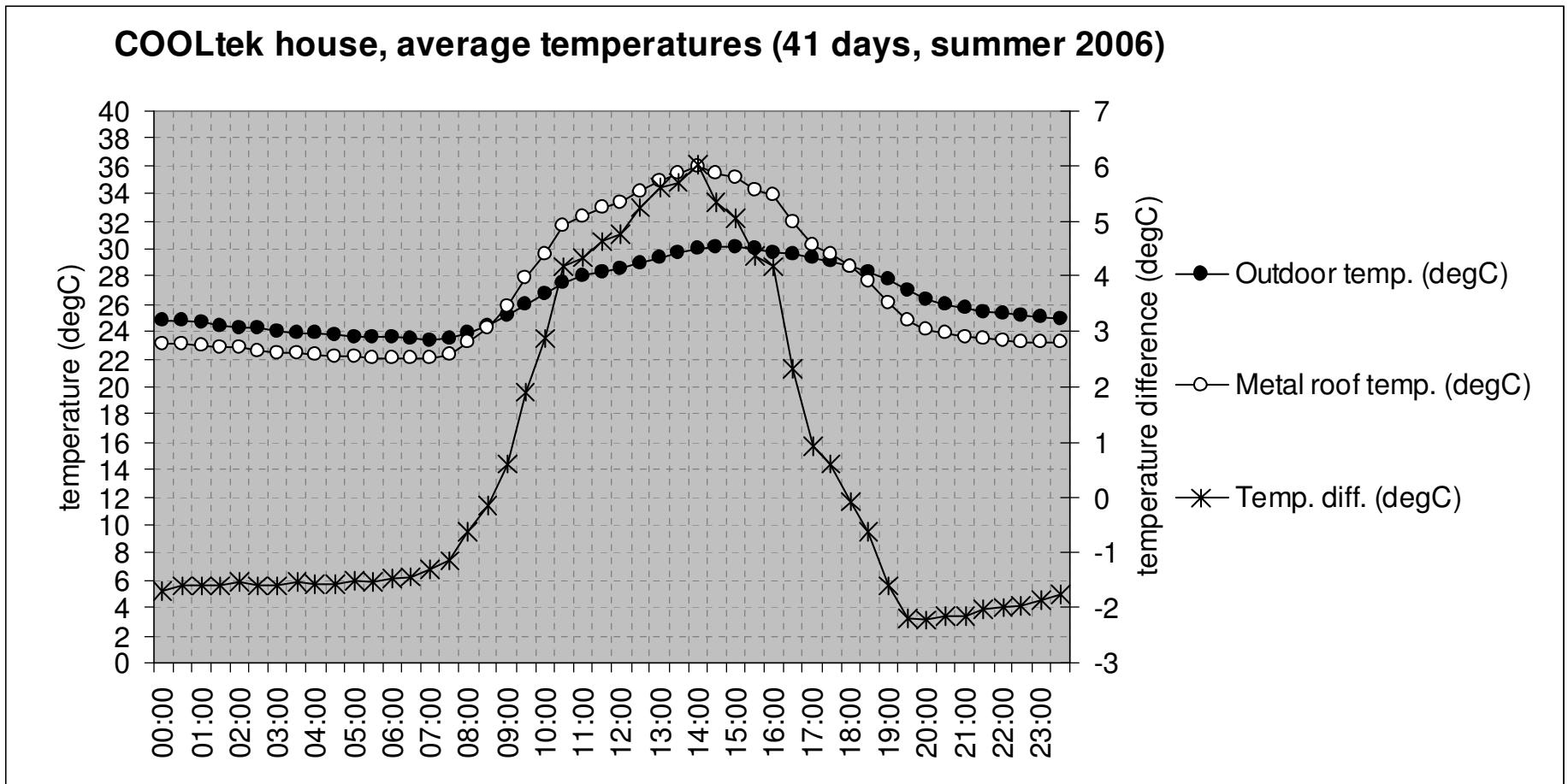
Appendix

Metal Roof Temperature

Metal roof temperature (CoolTek, 3 July - 12 August)



Metal Roof vs. Outdoor Temp.



Comment: At night the roof temperature is about 1.5 °C lower than the outdoor temperature due to radiation to the night sky.

Correspondence with CoolTek (1)

- [Comment by CoolTek](#) : Firstly, the original design for the ventilation system was to provide cooler air mainly during any unoccupied period of the house, when we were away and the air conditioning was switched off. A 'sealed' insulated and unventilated COOLTEK designed house without the air conditioning running would just keep getting hotter.
- [Answer by Gregers](#): OK, I understand and will correct the original design intend in my ppt.

NB. The points in this correspondence have been implemented in the slides

Correspondence with CoolTek (2)

- [Comment by CoolTek](#) : We understood that the original reason for carrying out the measurements was due to CK Tang's concern on CO2 levels in our 'sealed' house. The concern over sinking air conditioned air was secondary. As the concept of a 'sealed' house is new to Malaysia, it would be helpful to us when talking to Malaysians, if we could quote your findings that a sealed house with a COOLTEK ventilation system will give safe CO2 levels most times.
- [Answer by Gregers](#): Yes, you are definitely welcome to quote that the CO2 findings are within the safe range. However, don't forget that many Malaysian house will be more densely populated than your house. Sometimes, 3 generation will be staying in a house your size, hence, CO2 levels will also be higher. CK's principal concern was the CO2 levels, whereas my principal concern was the reversed flow in the ground cooled ventilation pipes.

NB. The points in this correspondence have been implemented in the slides

Correspondence with CoolTek (3)

- [Comment by CoolTek:](#) Your findings, that dense air conditioned air falls down the ventilation pipes, we agree with. Our suspicions why this happens differs from yours. The chimney has, as well as pipes from the air conditioned area, vent holes from both the foyer and the roof space. That is, ventilation chambers/pipes and solar chimney do not form a completely isolated air system. At around 7-8am, our habit has been to open the front door and garage doors to vent the non air con area with cooler air. This allows the chimney to be fed through the loft vents rather than taking air from the air conditioned area, thus cool air is no longer pulled up through the chambers. Attached Excel file has a graph of readings we took with our Davis weather station equipment during a 3 day trip to Singapore last weekend. We left at 8:45am on 1st Oct and returned to the house at 4:00pm on 3rd. You will notice there was no significant drop in temperature or absolute humidity at 8:00am on either of the two unoccupied mornings.
- [Answer by Greger:](#) OK, interesting new information. I will revisit my analysis. And thanks for your graphs during the unoccupied period. From the temperature data I can see that the air-conditioning has not been running during this period. Hence, the absolute humidity indoors and outdoors will be about the same, so it is difficult to conclude anything about the direction of the air-flow in the ground cooled ventilation channels. Perhaps you could try to redo the measurements, either for an unoccupied house with the air-conditioning running or during house occupation but without opening the front door and garage doors. Let us discuss a new run of measurements.

NB. The points in this correspondence have been implemented in the slides

Correspondence with CoolTek (4)

- [Comment by CoolTek](#) : Using our weather station equipment for the first time since leaving England, and with the external temperature and humidity sensors in the vent pipes, we have noticed there seems to be a pattern of barometric pressure readings with marked dropping pressure from 4:00pm onwards, followed by rising pressure from 8:00pm onwards. Changes in barometric pressure could affect the air flow through the ventilation system.
- [Answer by Gregers](#): Daily changes in barometric pressure could give rise to some 'daily breathing effect' in the ventilation pipes, i.e. air flowing in and out of the pipe at certain times. However, it is unlikely that changes in the barometric pressure would be the main cause for such air flow. It could be interesting to check for a correlation between barometric pressure and air flow direction for our next measurement run. From your current observation of changes in barometric pressure there does not seem to be a strong correlation to the measured air flow direction.

NB. The points in this correspondence have been implemented in the slides