Project: Analysis of The Cooling Load of Building

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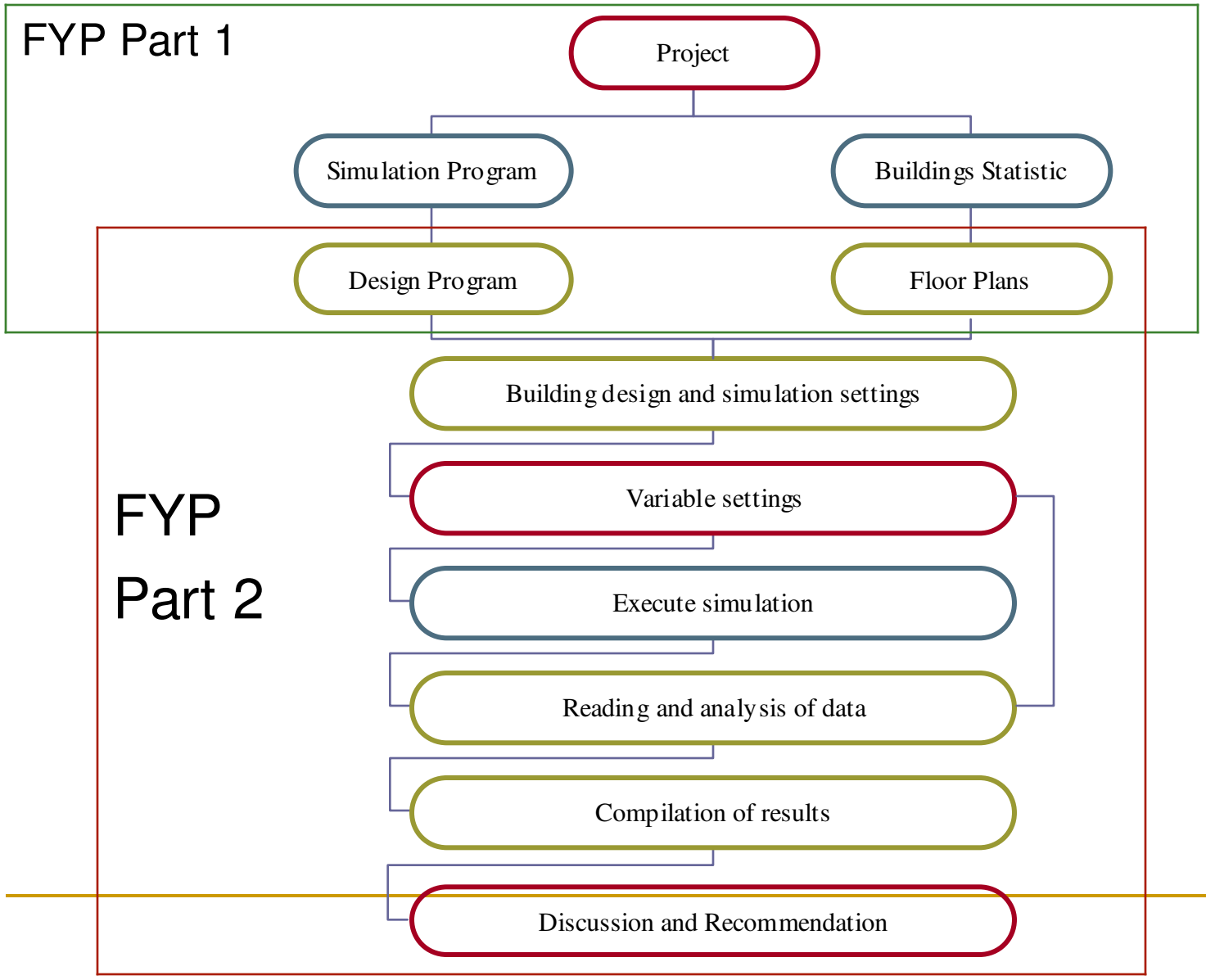
Objective

- To lower the cooling load of the building by investigating the influence of house structure:
  - Walls
  - Doors
  - Roofs
  - Ceilings
  - Floors
- To decrease the electricity bill usage.
- Reduces pollution to the environment.

Methods of Investigation



Software

- Building Energy Simulation Program

EnergyPlus

- Building Design Program

DesignBuilder

EnergyPlus & DesignBuilder

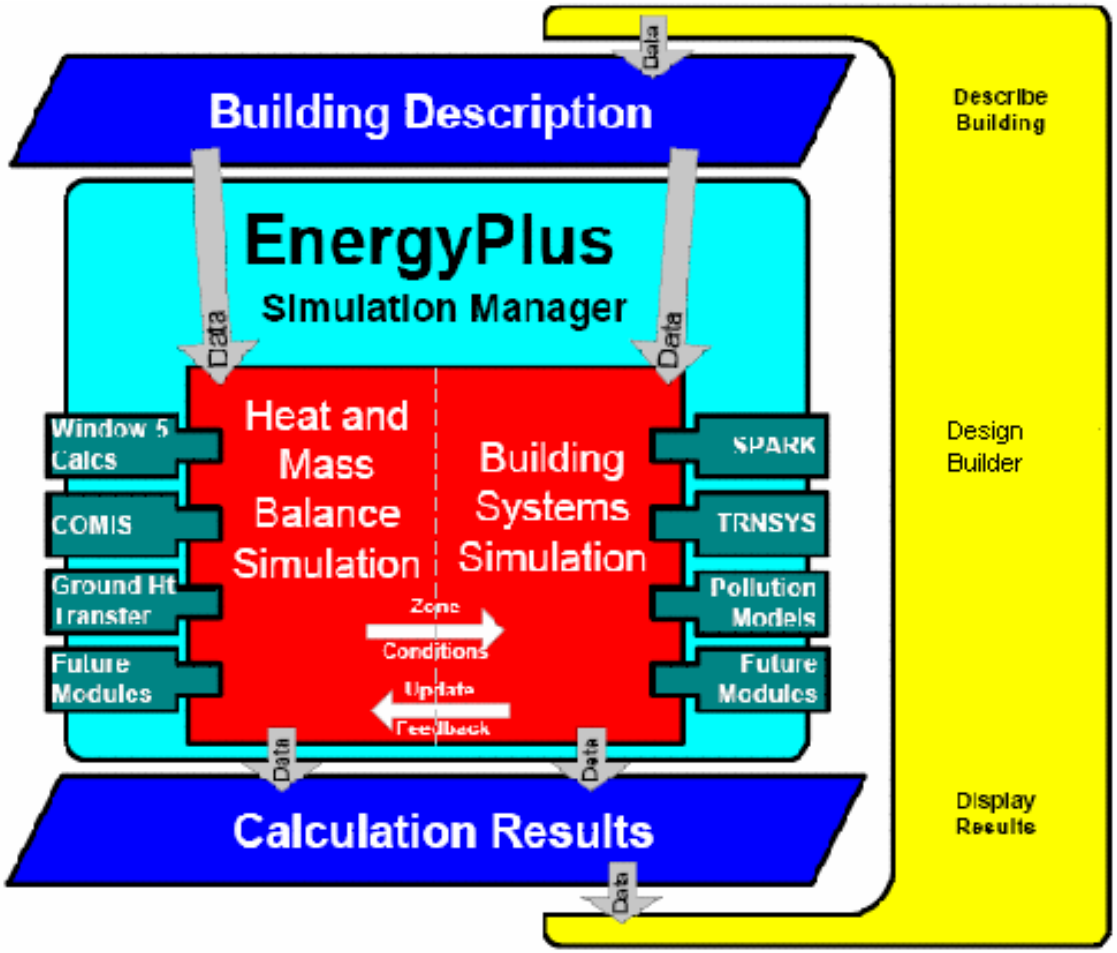
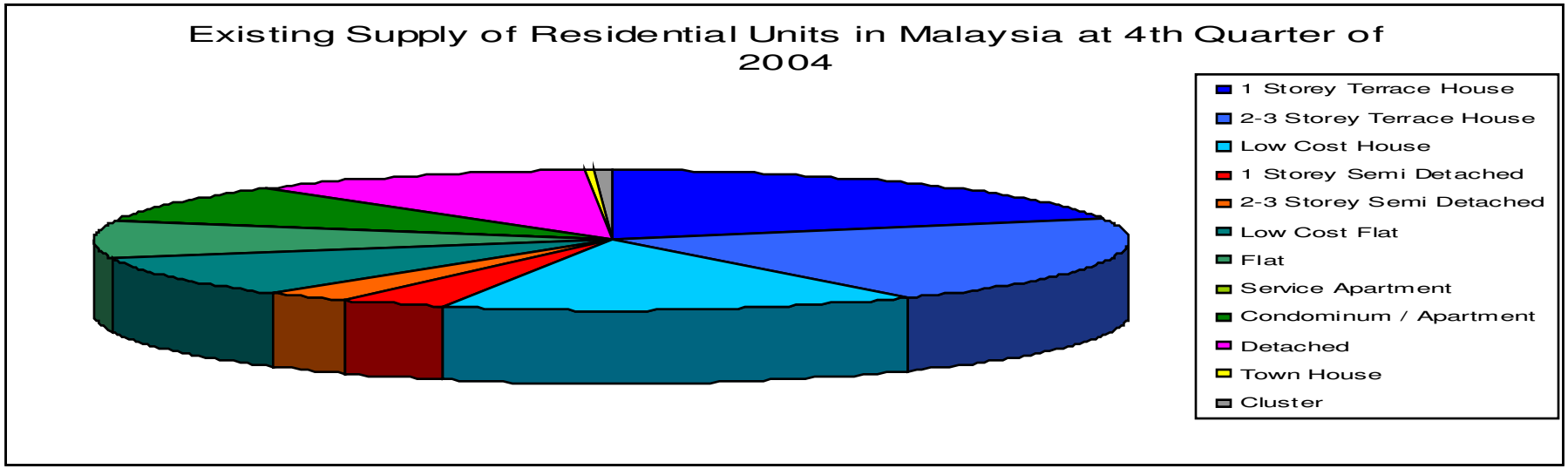


Figure 1.0: EnergyPlus – The Big Picture

Statistical Review



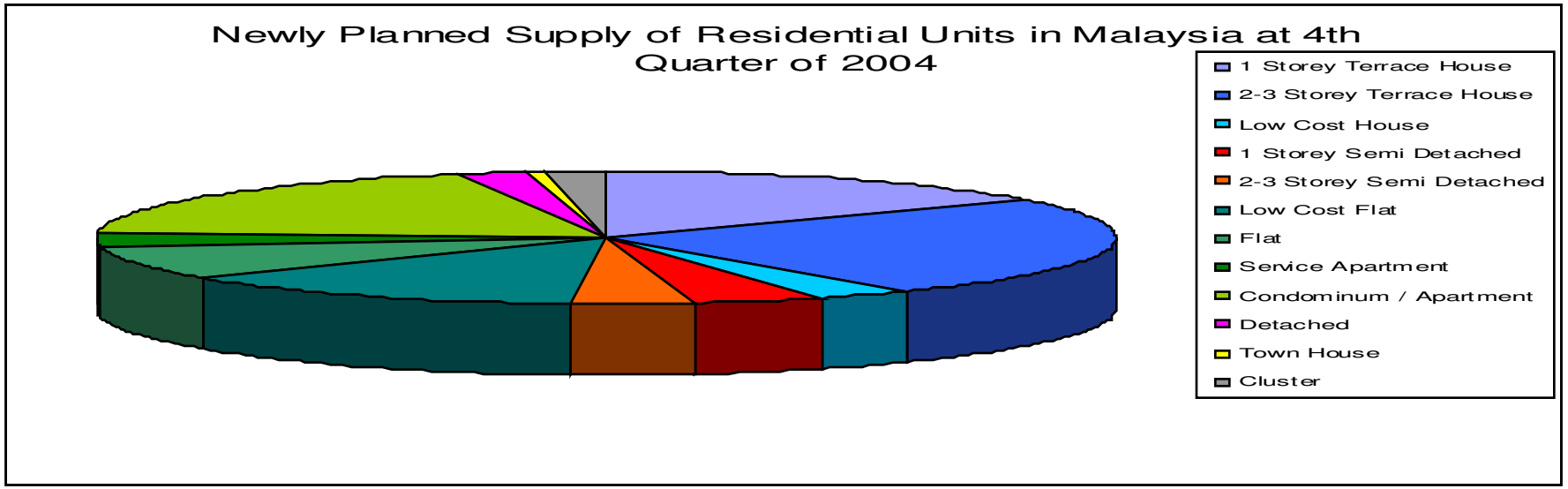
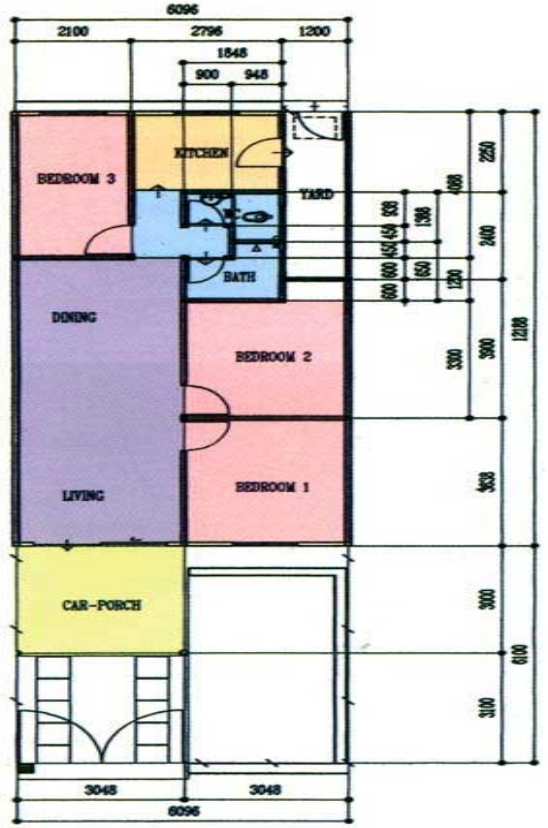


Figure 1.1: Existing supply of residential units in Malaysian at 4th Quarter of 2004
Figure 1.2: Newly planned supply of residential units in Malaysian at 4th Quarter of 2004

Houses: Terrace House



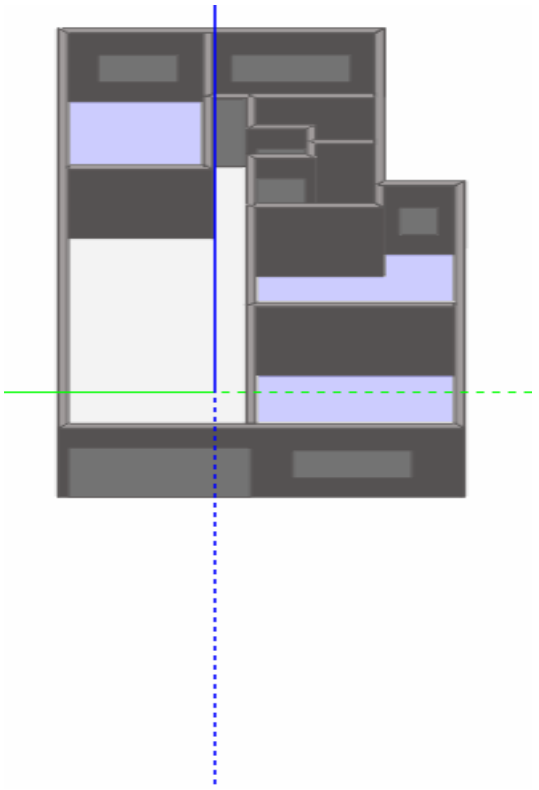


Figure 1.3 (left): Floor plan for the terrace house obtained online
Figure 1.4 (right): The terrace house designed using DesignBuilder

Terrace House: (Cont)

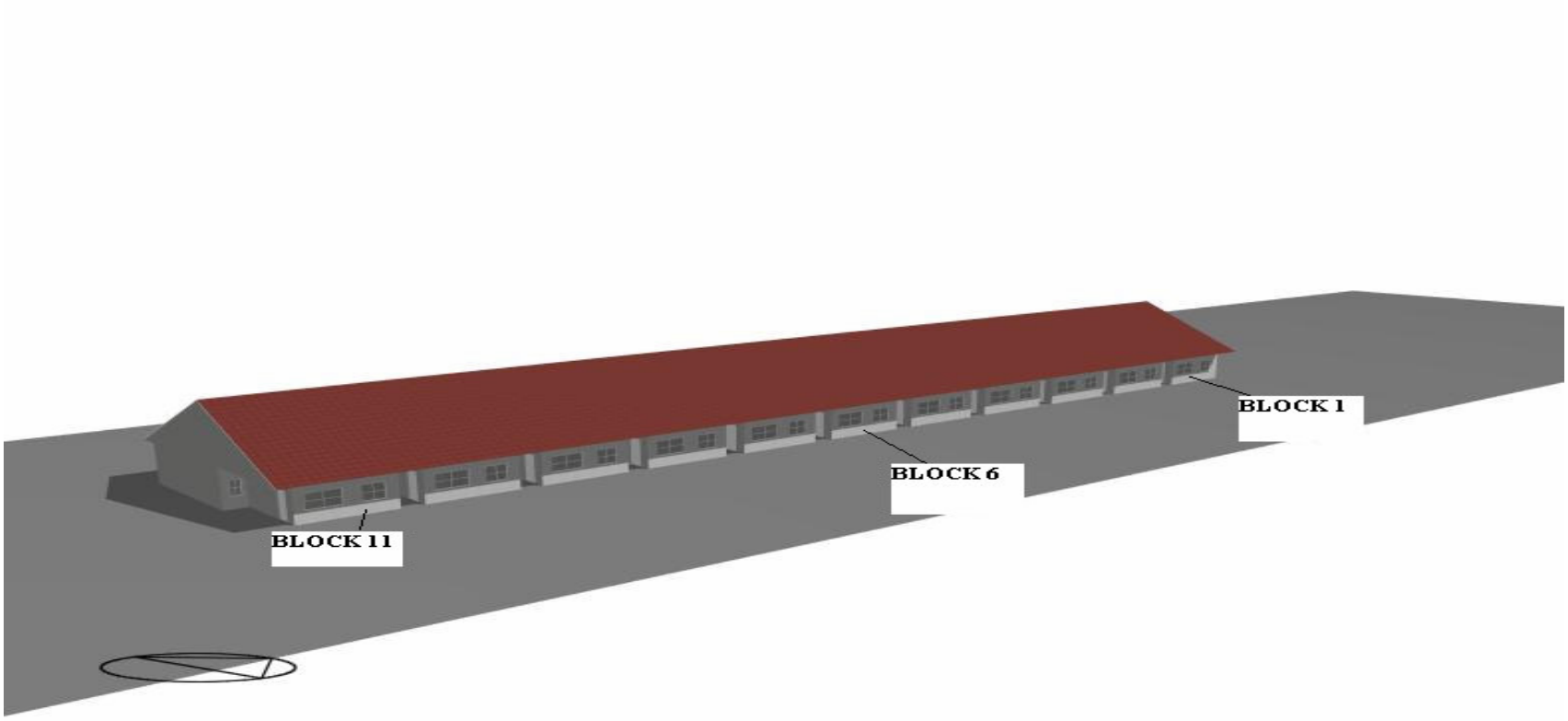


Figure 1.5: Visualization of the terrace house with north points with DesignBuilder

Cooltek House

Figure 1.6: Photo of the Cooltek House

Cooltek House (Cont)

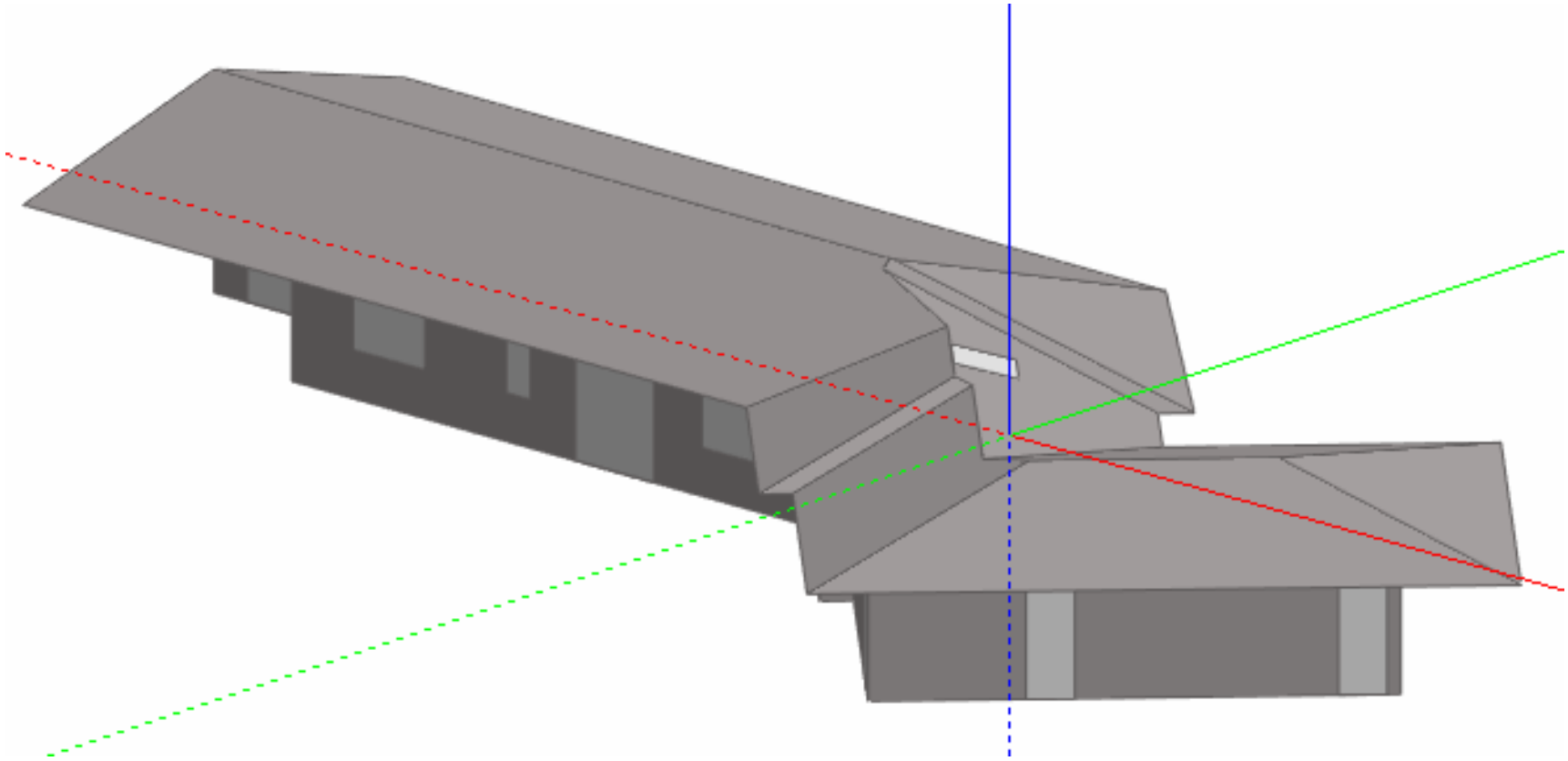


Figure 1.7: Cooltek House illustrated with DesignBuilder

Traditional Melaka House

Figure 1.8: Photo of the traditional Melaka house

Traditional Melaka House (Cont)

Figure 1.9: Visualization of the traditional Melaka house with DesignBuilder

Bungalow

Figure 1.10: Visualization of the Bungalow using DesignBuilder

Parameter Study

Influence on the cooling load through the:

1) Walls
2) Doors
3) Roof
4) Ceilings
5) Floors

Parameter Study (Cont):

- House: Terrace house
  - Walls: Malaysia Wall
  - Doors: Wooden Door
  - Roof: Malaysian Roof
  - Ceilings: Malaysian Ceilings
  - Floors: Ceramic Floors
- Rooms with air conditioner: Bedrooms, Living Hall
- Cooling capacity for Bedroom 1: 1.115 kW
- Cooling capacity for Bedroom 2: 0.474 kW
- Cooling capacity for Bedroom 3: 0.642 kW
- Cooling capacity for Living Hall: 2.477 kW
- Air conditioner temperature set point: 22 ℃
- Day of simulation: 21st March 2002

Results

- The comfort temperature, in unit of ℃ is taken as the result as it is the temperature that is it felt.
- The heat gain, in unit of kW is meant by the energy gain through the construction material.
- The total design cooling requirement, in unit of kWh is the total energy required to cool the house to the set point temperature.
- The *U*-value of the material, in unit of W/m^2K is the reciprocal of its thermal resistance value, *R* of the material.

The Walls

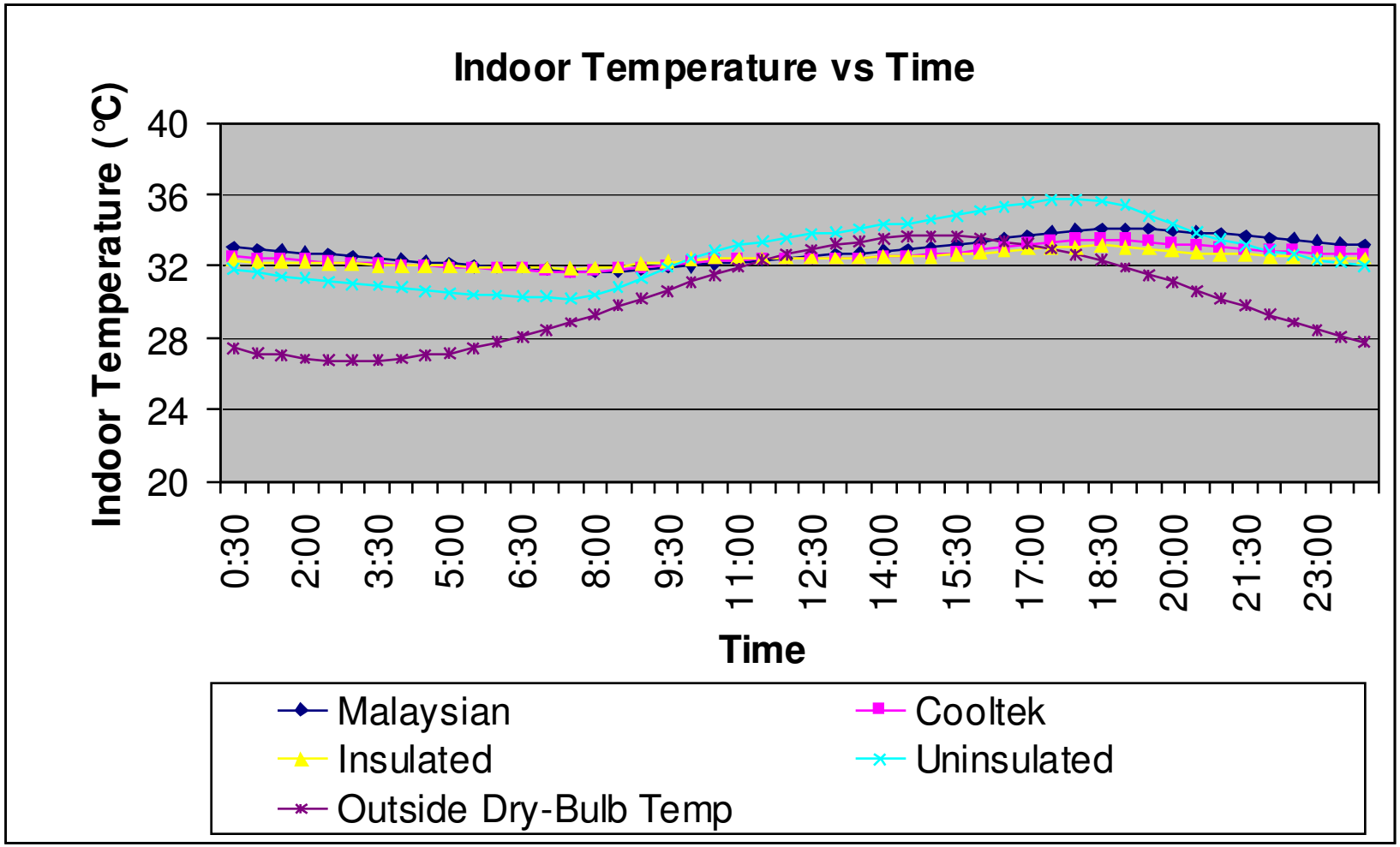


Figure 2.1: Indoor Temperature vs. Time for terrace house with different walls; Air conditioner OFF.

The Walls (Cont)

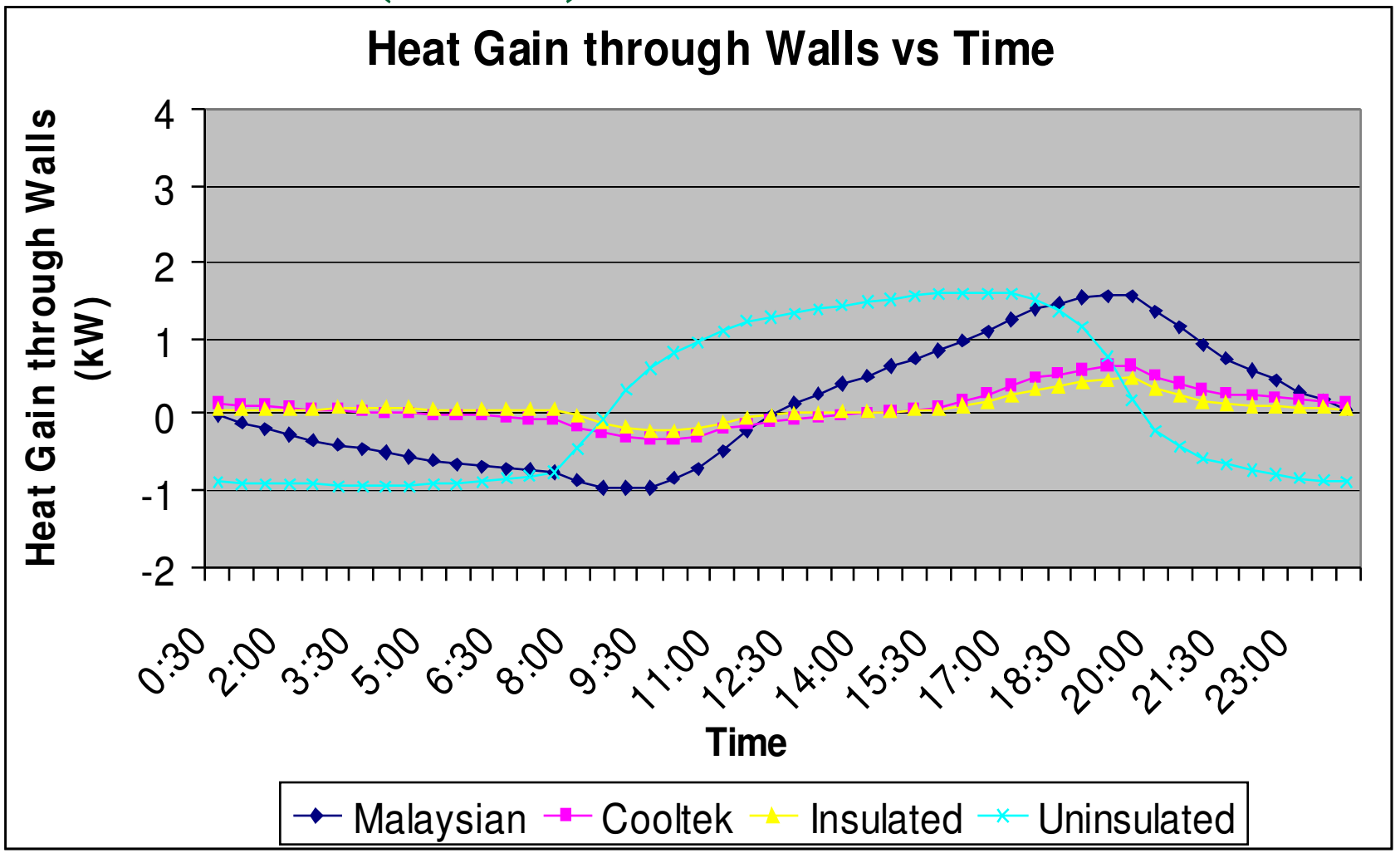


Figure 2.2: Heat Gain through walls vs. Time for terrace house with different walls; Air conditioner OFF.

The Walls (Cont)

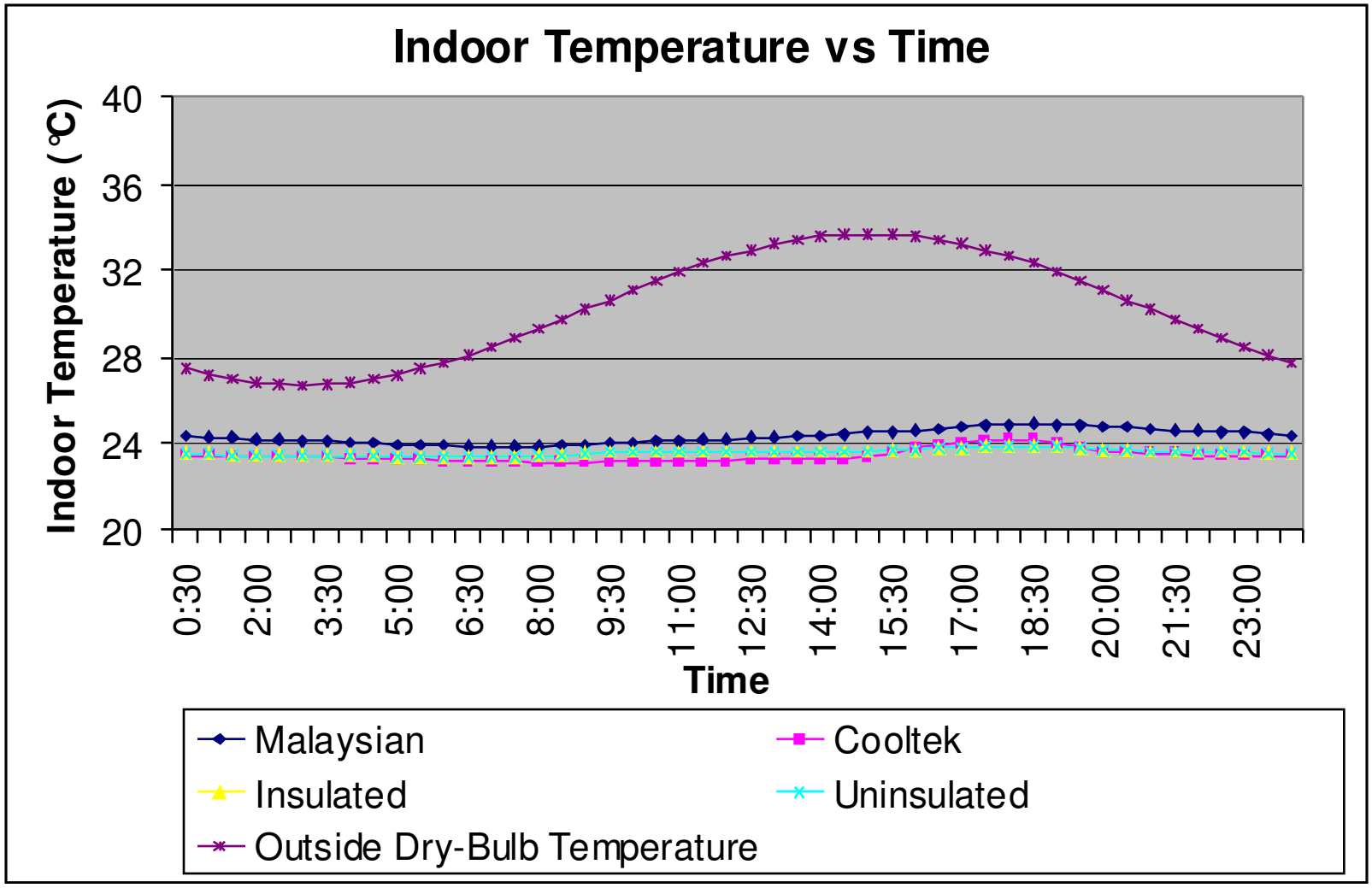


Figure 2.3: Indoor Temperature vs. Time for terrace house with different walls; Air conditioner ON.

The Walls (Cont)

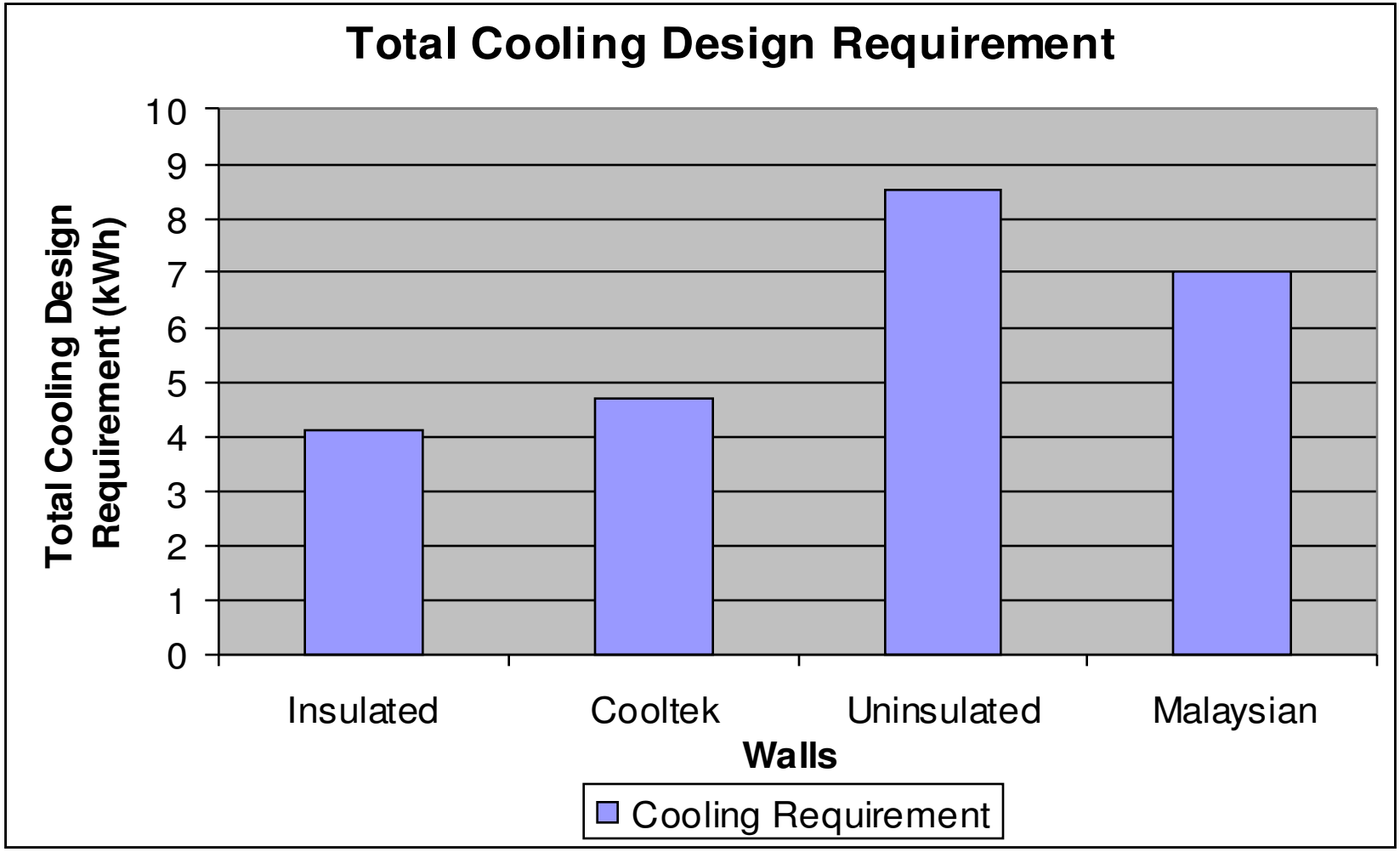


Figure 2.4: Cooling Design Requirement for terrace house with different Walls

The Walls - Discussion:
Return of Investment Calculation

- Electricity bill for 1kWh: RM0.25
- Change from Malaysian Wall to Cooltek Wall: *7 – 4.71=* 2.29kWh
- Equivalent amount in electricity bill: *0.25 x 2.29 =* RM0.5725
- Cost for 1 Aerated Concrete Block: RM3.00
- Surface Area Covered: 0.112m^2
- Cost For 1 Conventional Brick: RM0.05
- Surface Area Covered: 0.016m^2
- Approximate Surface for Terrace House: 188.502m^2
- Additional Initial Cost Incurred:
  3 x (188.502 / 0.112) – 0.20 x (188.502/0.016)= *RM2692.88*
- Breakeven period:
  2692.88 / 0.5725 = 4703 days = 12.88 years

The Walls – Discussion (Cont)

- Less fluctuation of temperature may lead to less wall maintenance (extreme high and low temperature causes fatigue to materials).
- The cost of electricity is considered as constant, it adds the advantage as the cost always increase in future.
- The breakeven will actually less then 12.88 years.

The Doors

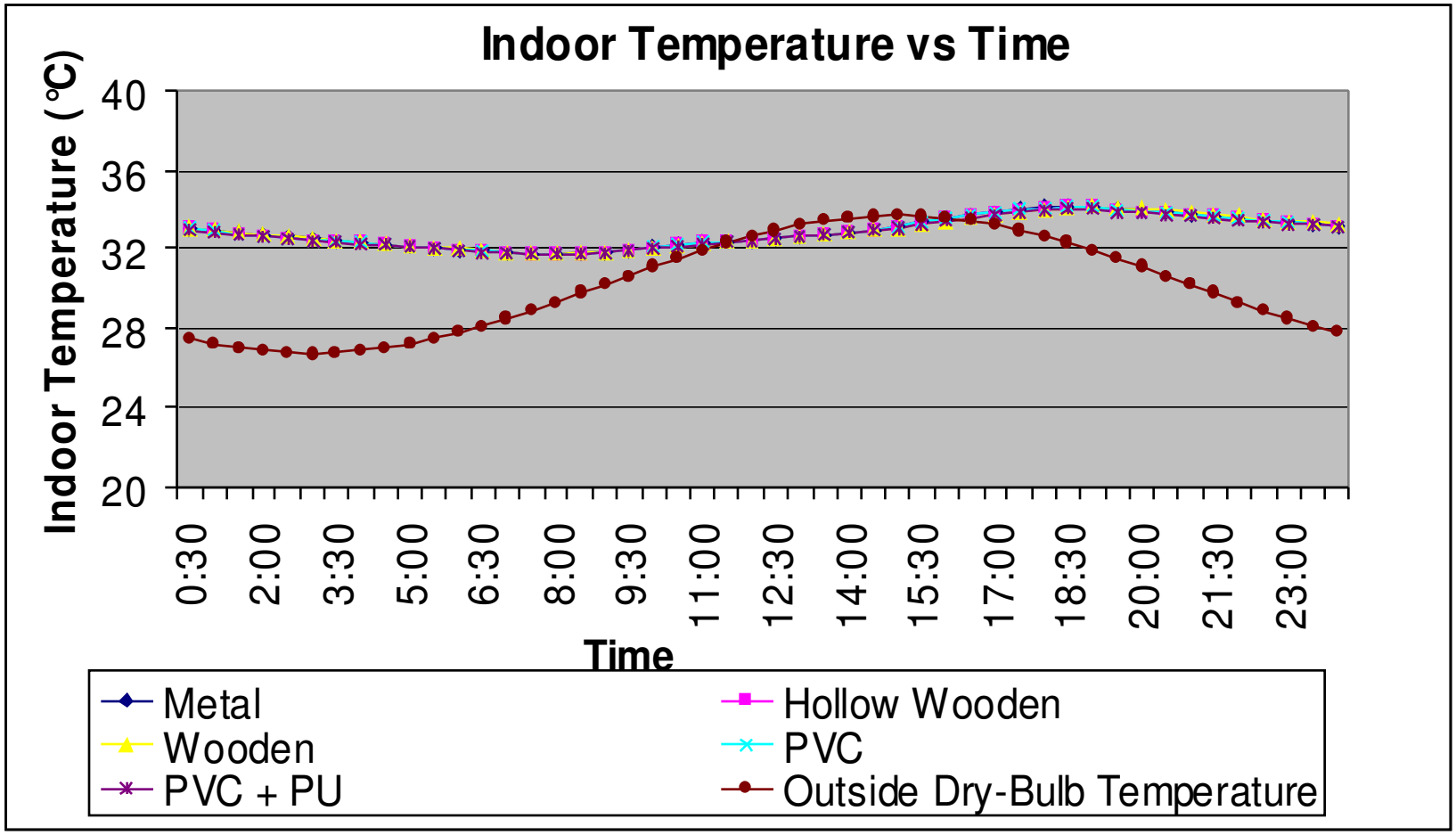


Figure 2.5: Indoor Temperature vs. Time for terrace house with different doors; air conditioners OFF

The Doors (Cont)

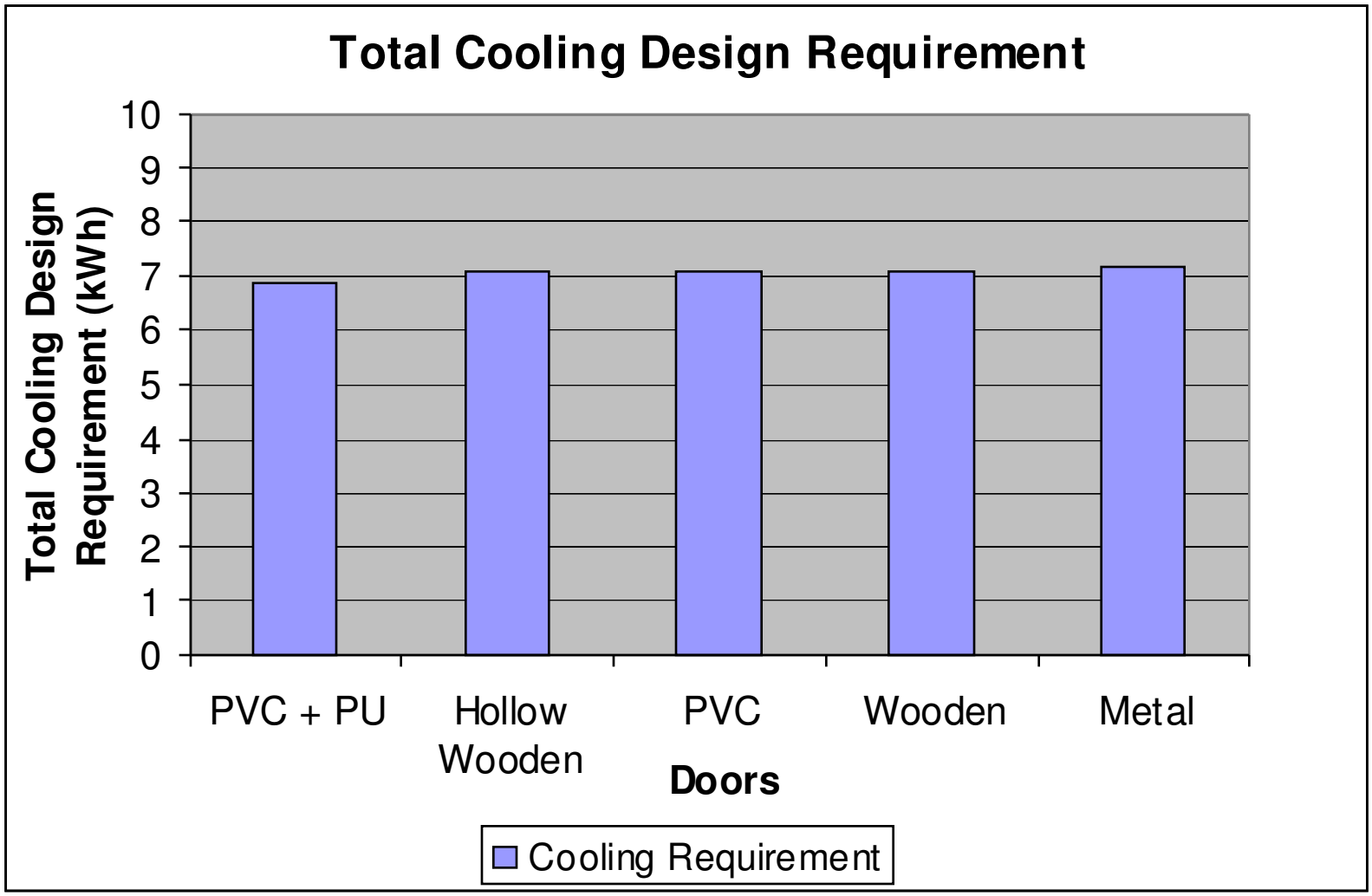


Figure 2.6: Cooling Design Requirements for terrace house with different Doors

The Doors - Discussion: Return of Investment Calculation

- Electricity bill for 1kWh: RM0.25
- Change from Wooden Door to PVC + PU Door:
  7.05 – 6.87 = 0.18kWh
- Equivalent amount in electricity bill:
  0.25 x 0.18 = RM0.045
- Cost for 1 PVC + PU Door: RM400
- Cost For 1 Wooden Door: RM180
- Additional Initial Cost Incurred:
  400 – 180 = RM220
- Breakeven period:
  220 / 0.045 = 4888.89 days = 13.39 years

The Doors – Discussion (Cont)

- If the house does not have air conditioner, the type of doors practically have no influence.
- If the house is equipped air conditioner, PVC + PU door is recommendable.
- If the air conditioner is meant to keep only one room cool, the PVC + PU door is the best choice as the door of the room because it will keep the cool air inside the room and door surface is not negligible.

The Roofs

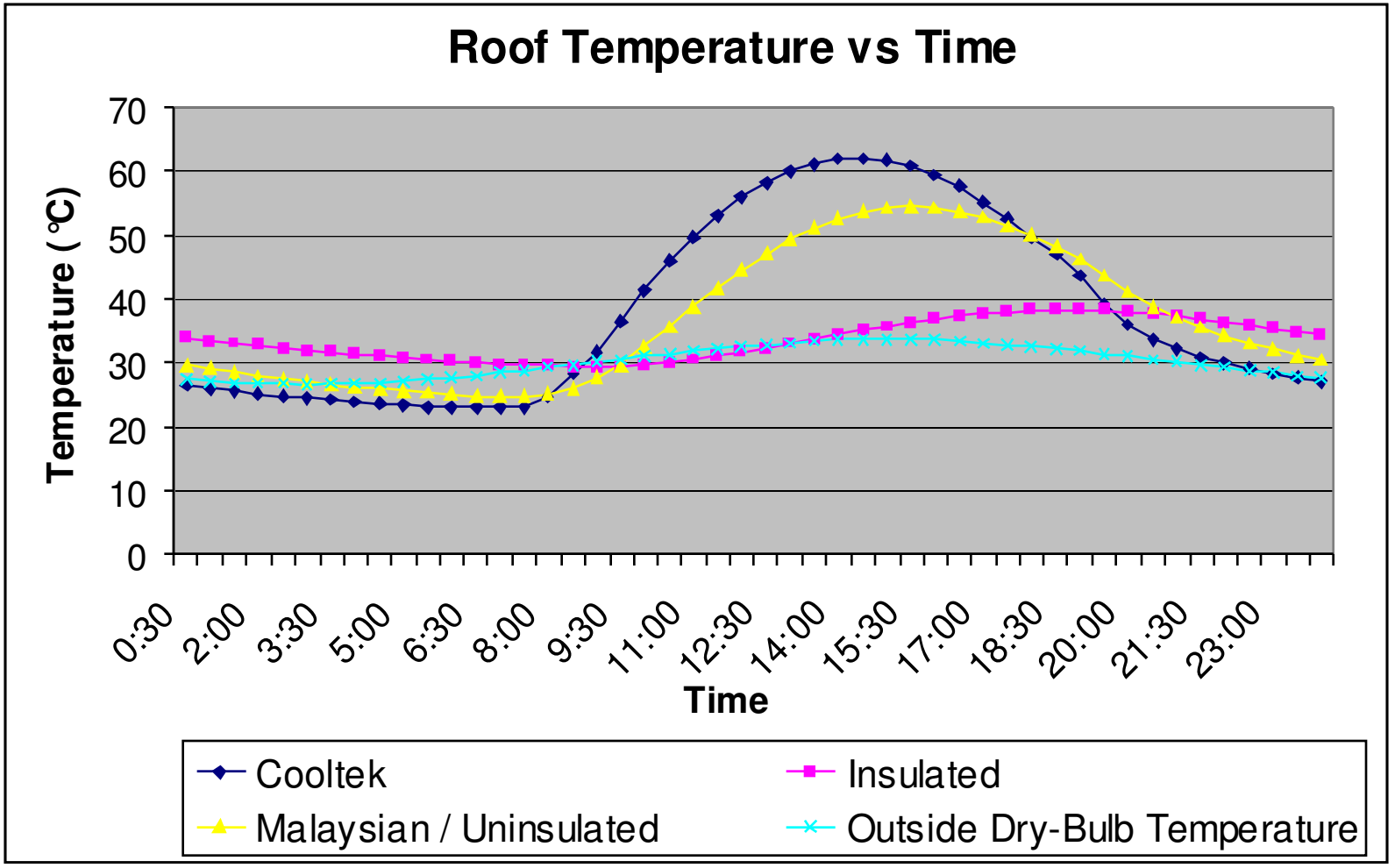


Figure 2.7: Roof Temperature vs. Time for terrace house with different roofs

The Roofs (Cont)

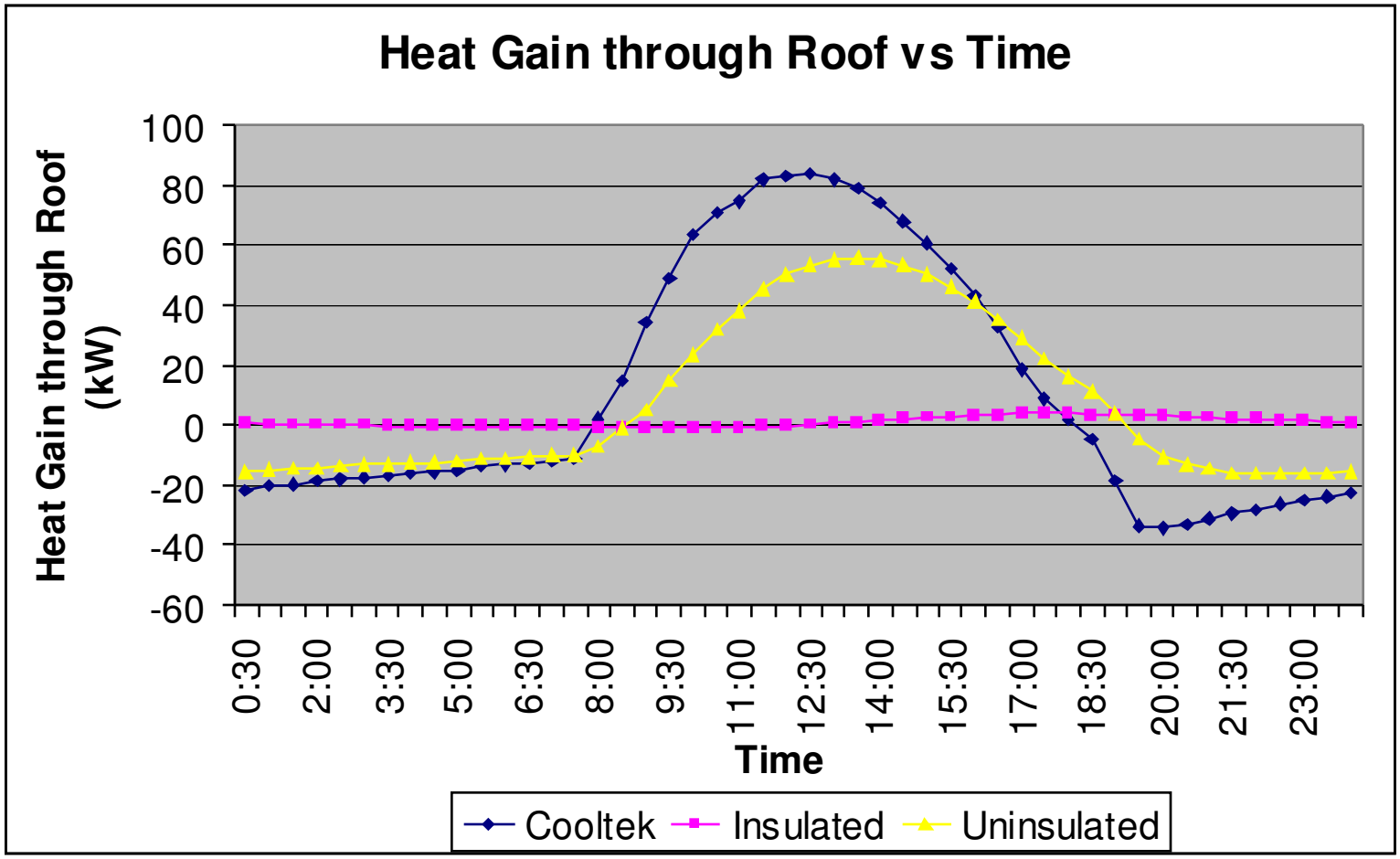


Figure 2.8: Heat Gain through roof vs. Time for terrace house with different roof

The Roofs (Cont)

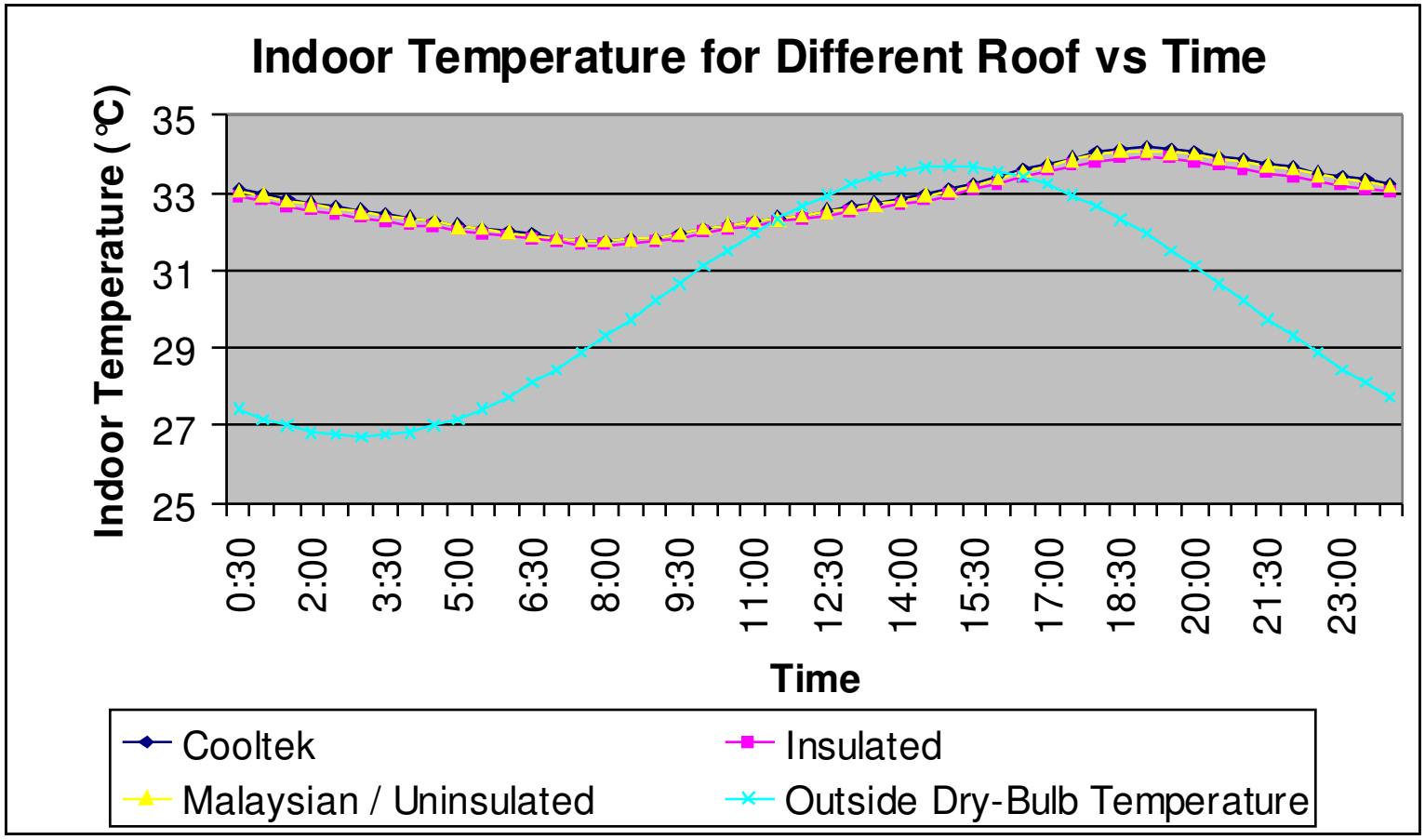


Figure 2.9: Indoor Temperature vs. Time for terrace house with different roofs; air conditioner OFF

The Roofs (Cont)

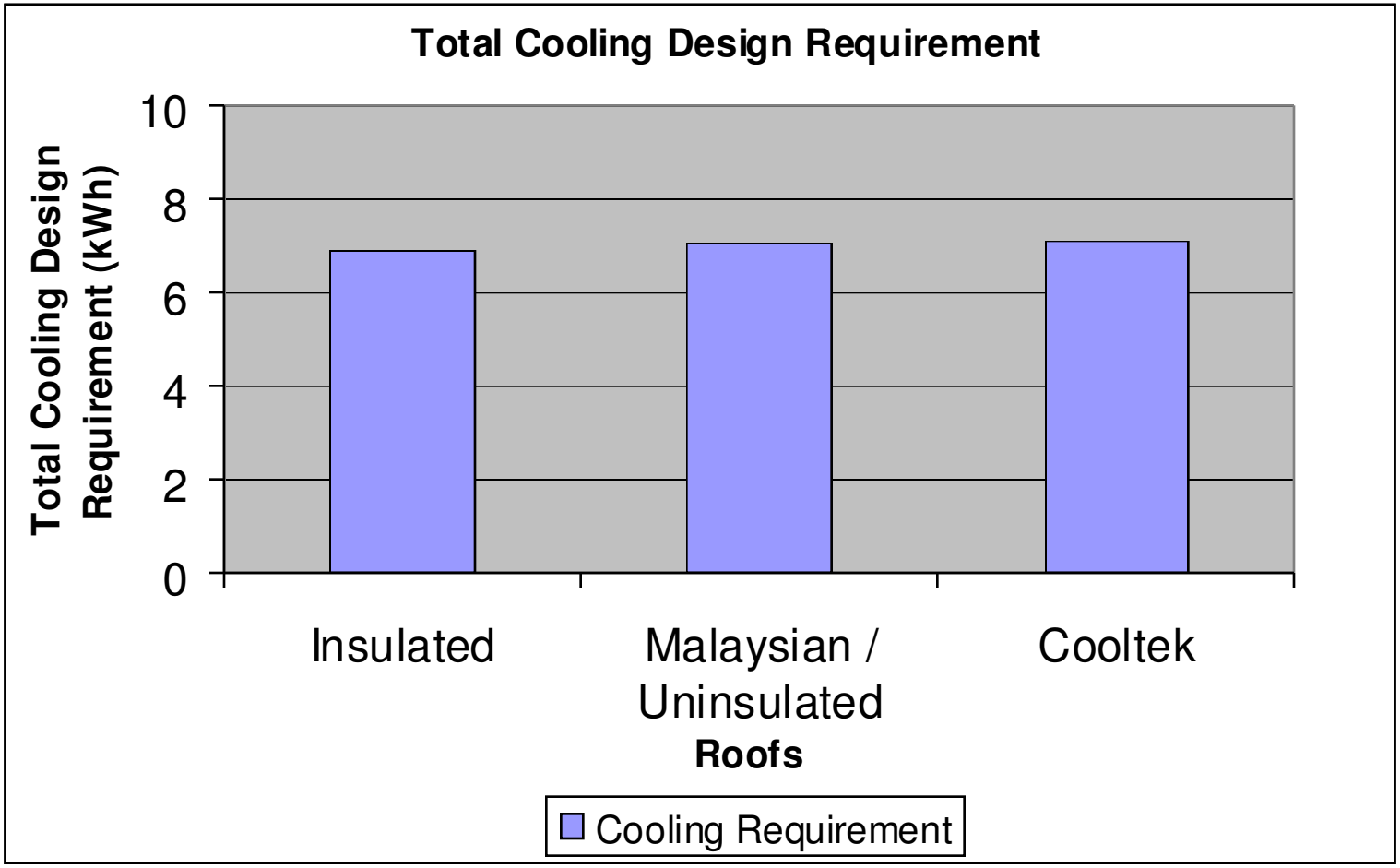


Figure 2.10: Cooling Design Requirements for terrace house with different roofs

The Roofs – Discussion

- Better insulated roof have a near constant temperature while poorly insulated roof have a high amplitude of fluctuation.
- However, the influence on indoor temperature among all types of roofs are insignificant.
- Because the roof is far too high from the inside of the house. As hot air rises and cool air descend and potential difference of the temperature is not high enough to conduct heat downwards.
- Cooltek roof can use evaporative cooling method to cool down the house if necessary. However, this method could not be proved in this project.

The Ceilings

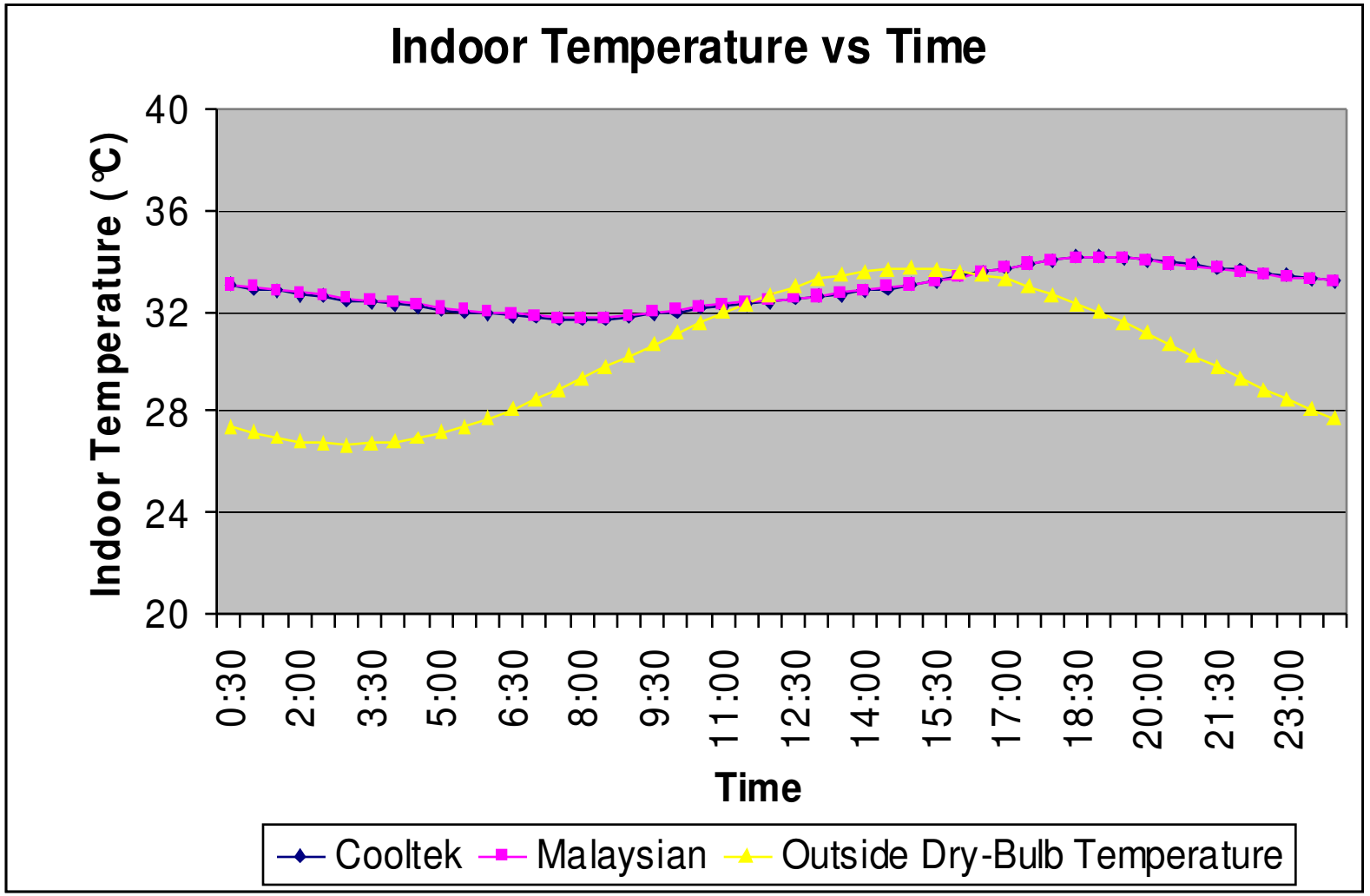


Figure 2.11: Indoor Temperature vs. Time for terrace house with different ceilings; air conditioner OFF

The Ceilings (Cont)

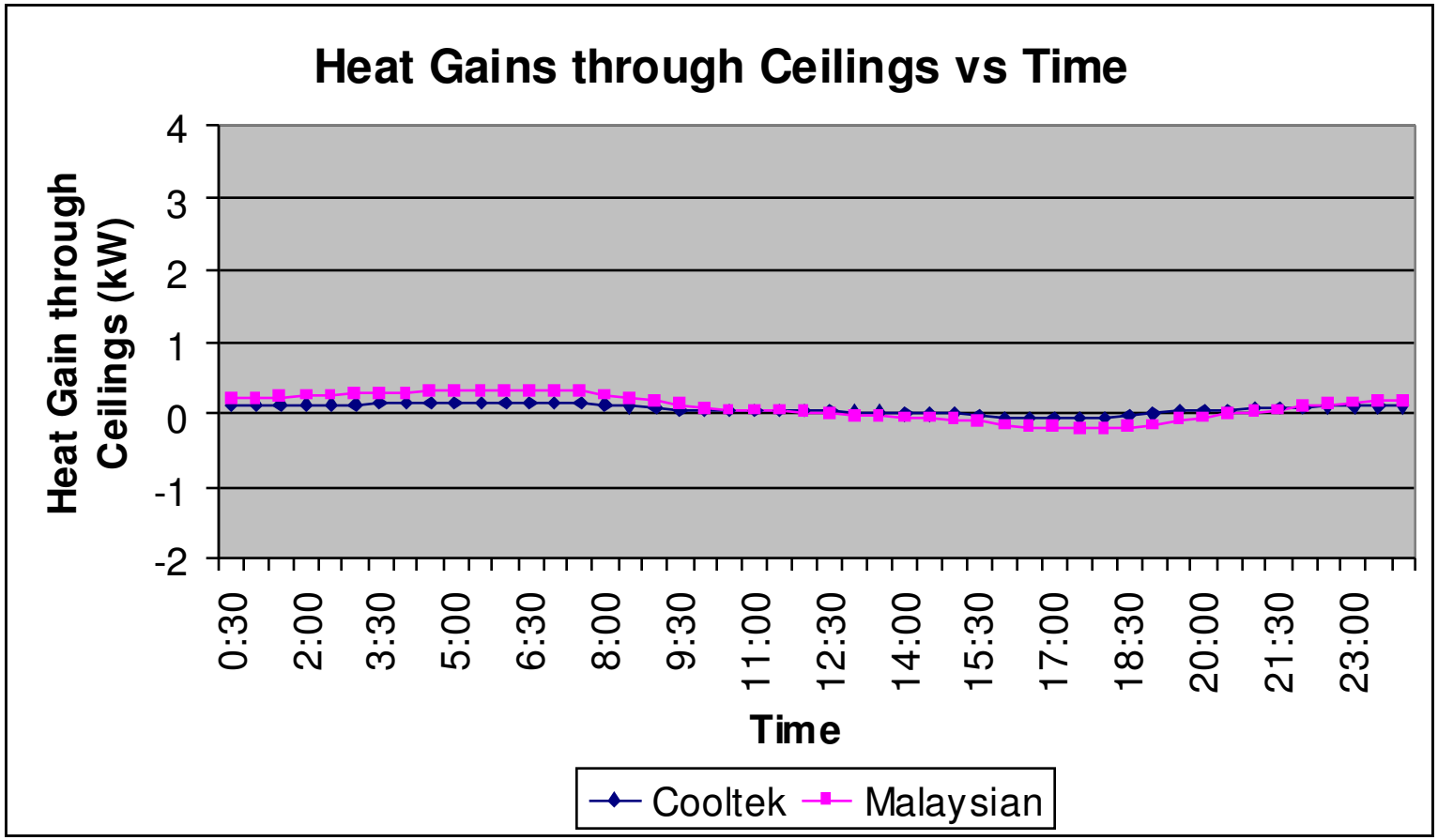


Figure 2.12: Heat Gains through Ceilings vs. Time for terrace house with different ceilings; air conditioner OFF

The Ceilings (Cont)

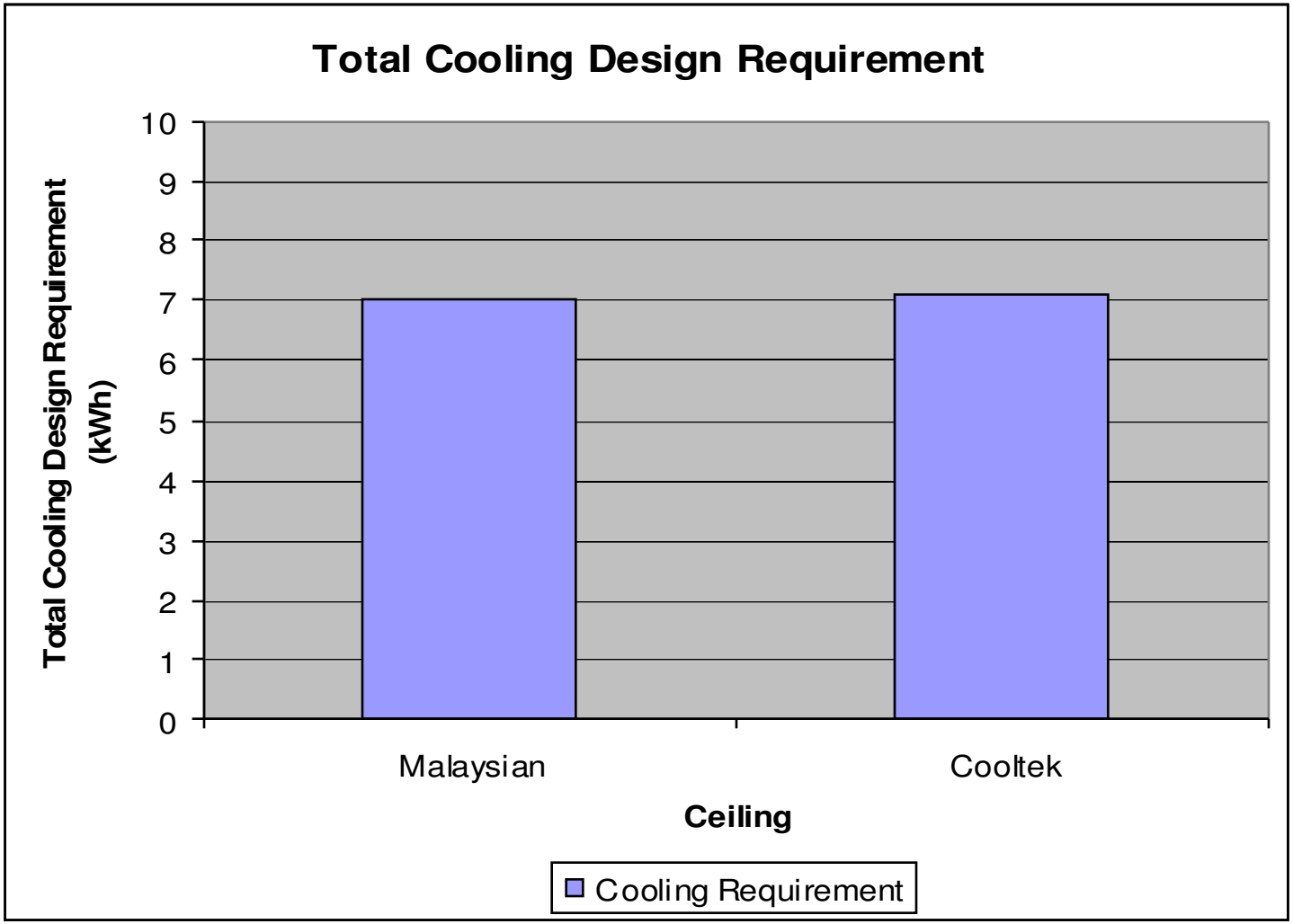


Figure 2.13: Cooling Design Requirement for terrace house with different ceilings

The Ceilings – Discussion

- The indoor temperature difference is insignificant.
- The amplitude of fluctuation between insulated and un-insulated ceilings too is also just barely noticeable.
- Even the cooling requirements for both ceilings are almost non-existence.
- Because the ceilings are located at the top part of the house. As hot air goes up and cool air descends, the potential of heat difference is not high enough to be of significant influence to the indoor temperature.
- This case is same for both air conditioners on and off. Therefore, the ceilings do not play a big part in making a difference in cooling load.

The Floors

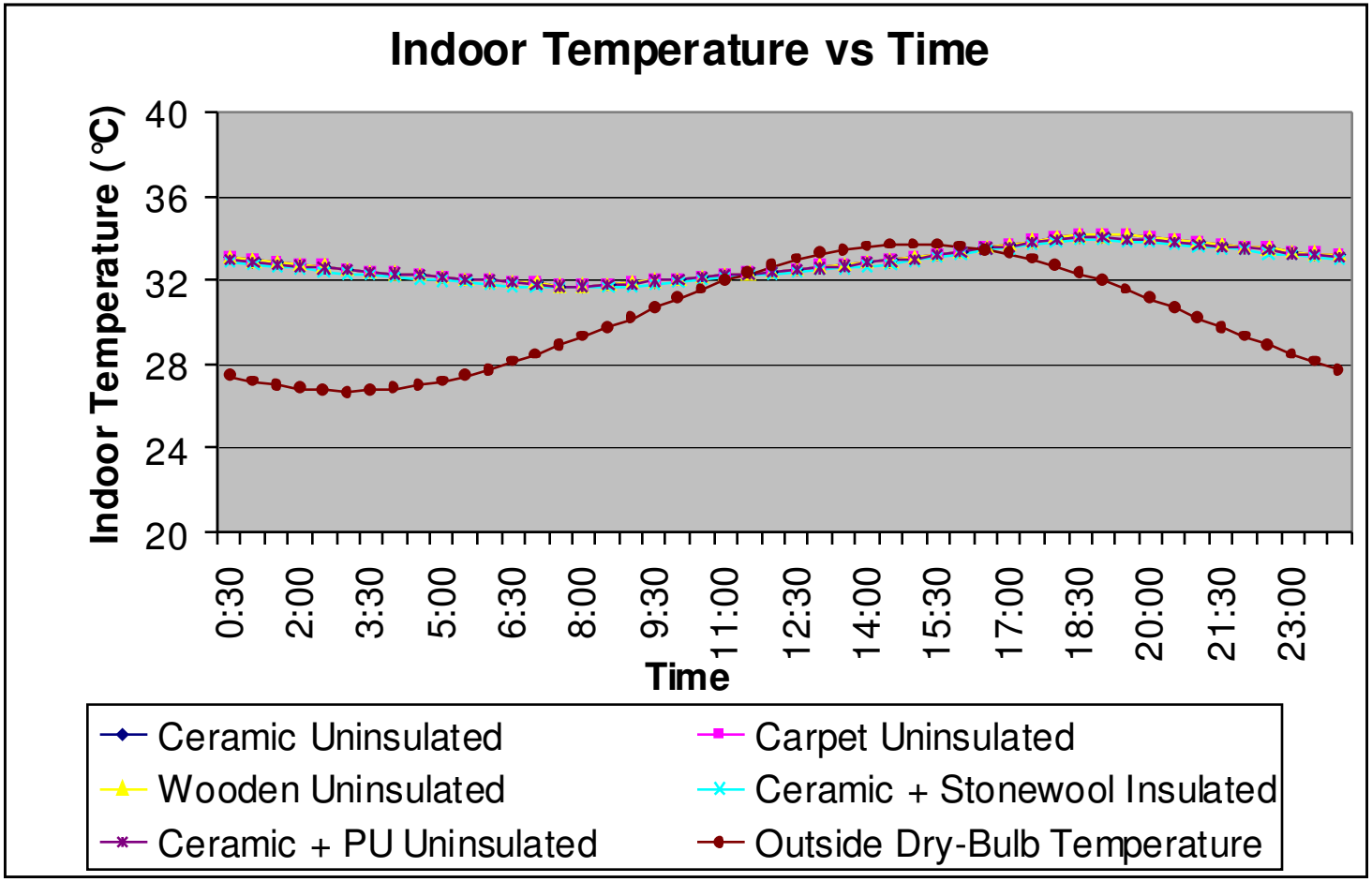


Figure 2.14: Indoor Temperature vs. Time for terrace house with different floors; air condition OFF

The Floors (Cont)

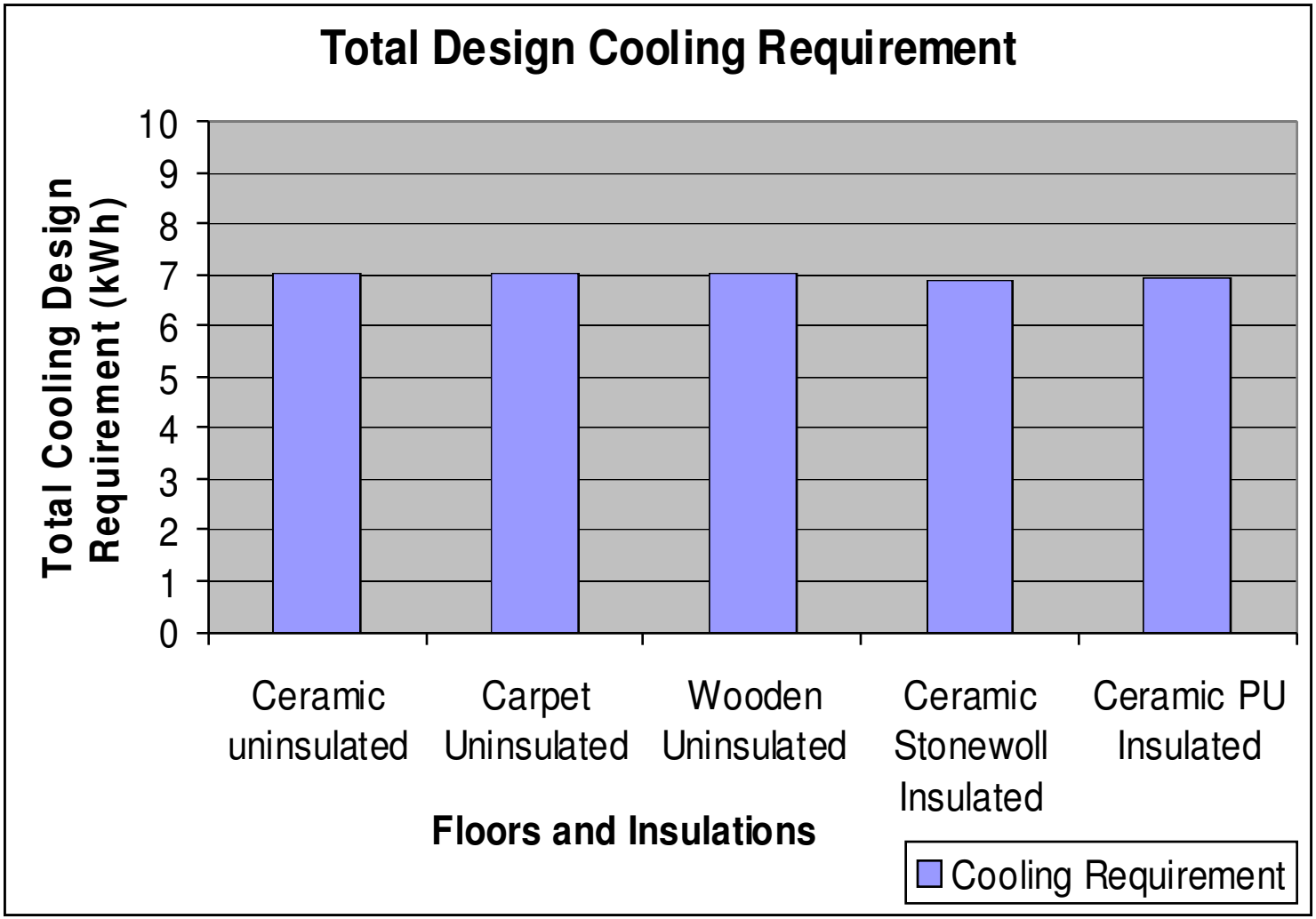


Figure 2.15: Cooling Design Requirements for terrace house with different floors

The Floors – Discussion

- The floors are divided into the floor types and its insulation in the simulation program,
- The floor types (carpet, wooden and ceramic floors) do not make much difference in the temperature of the house. This is because of its low height (≈10mm) which makes heat conduction through it relatively easy.
- The insulation layer produces a small difference in cooling requirement inside the house based on small difference in U-value.
- Insulates the house from the ground so less heat are lost through the ground.
- The floor insulations theoretically better applied to two-storey houses. If the 2nd floor is air conditioned (≈24 ℃), the temperature potential between the ground of the 2nd storey and the ceilings of the ground floor (≈33 ℃), would be large and would cause heat seep out through the ground of the room.
- Application of this insulation would make more sense than insulating the ground of 1st storey as the ground temperature set in this program is 25 ℃ and the air temperature in a air-conditioned room is approximately 24 ℃.

The U-value

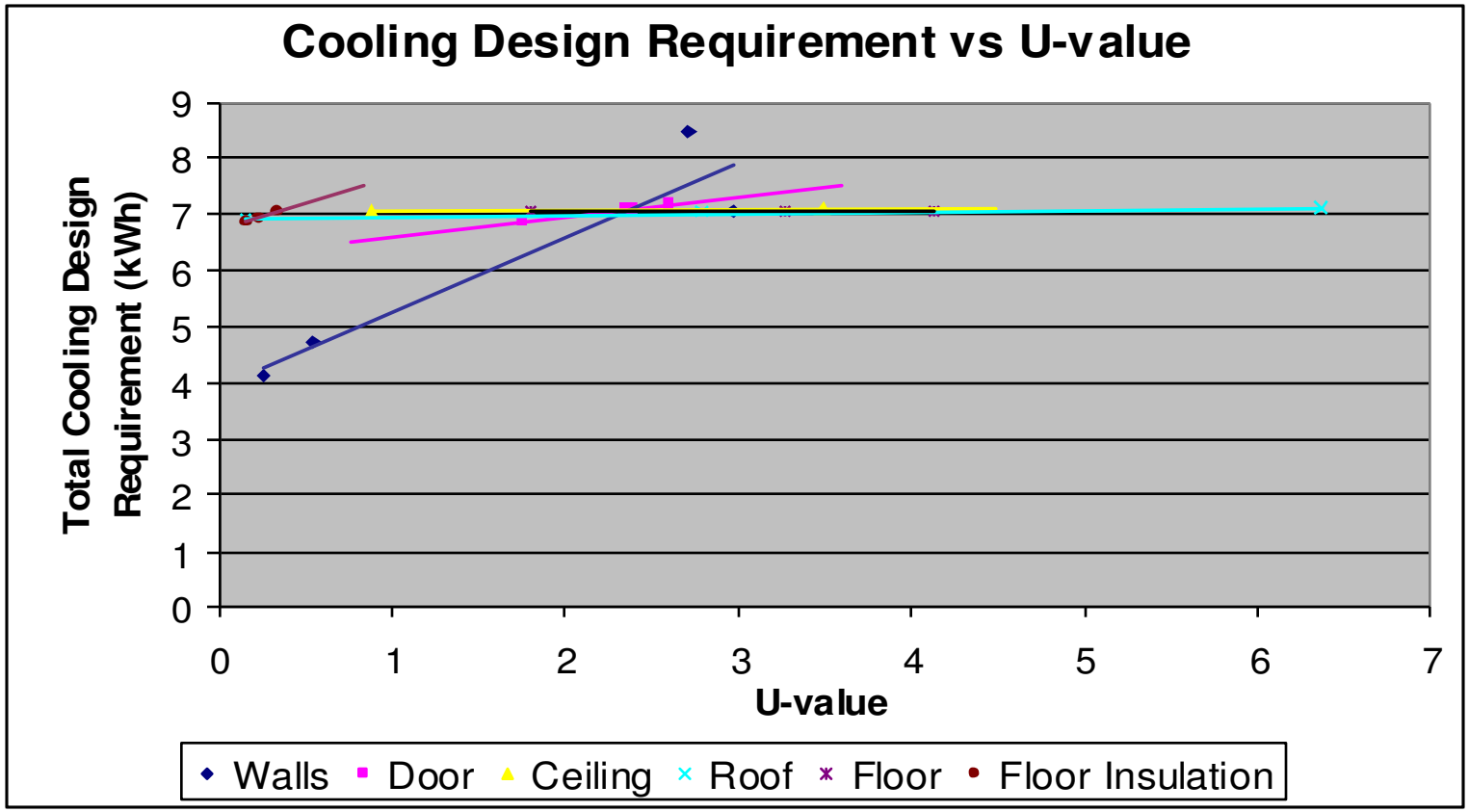


Figure 2.16: Cooling design requirement vs. U-value for different construction material

The U-value – Discussion

- Basically, the higher the U-value, the more cooling is required.
- Walls shows biggest influence on the building's cooling load; due to its surface area that are in contact with the environment and the sun, the main source of heat energy.
- Doors influence the indoor temperature by the amount or probability of total time it is left open, as every time the door opens, it leaks the cool air. However, the door has its limitation due to its surface area in contact with the environment.
- The floor insulation can give benefits depending on the indoor and ground temperature.
- Ceiling and Roof plays a smaller part; because it is on the higher part of the house. As hot air goes up and cold air descends, the amount of influence they exercise over the indoor temperature is minor.

Different Houses

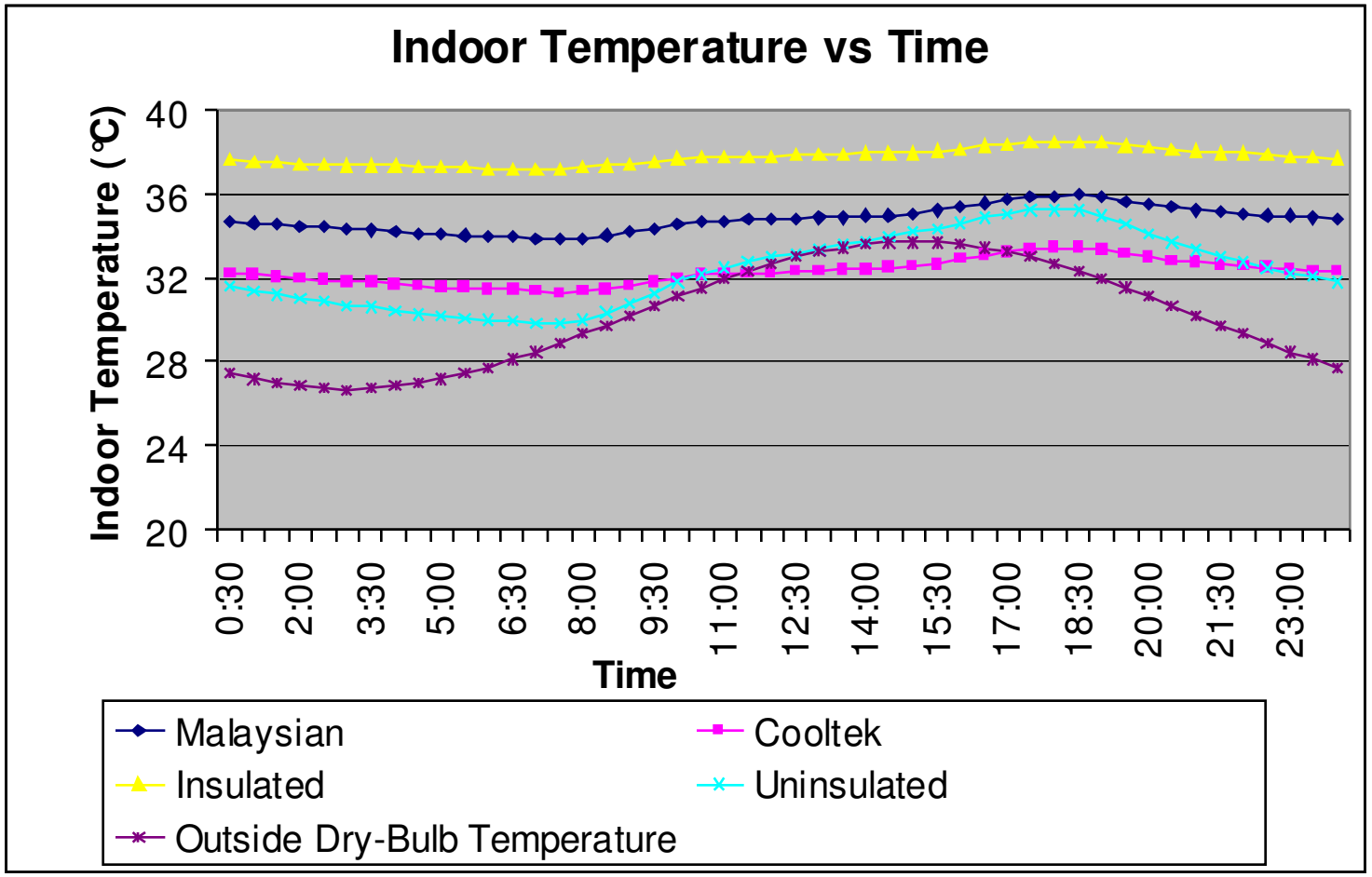


Figure 4.17: Indoor Temperature vs. Time for terrace house with different insulation templates

Different Houses (Cont)

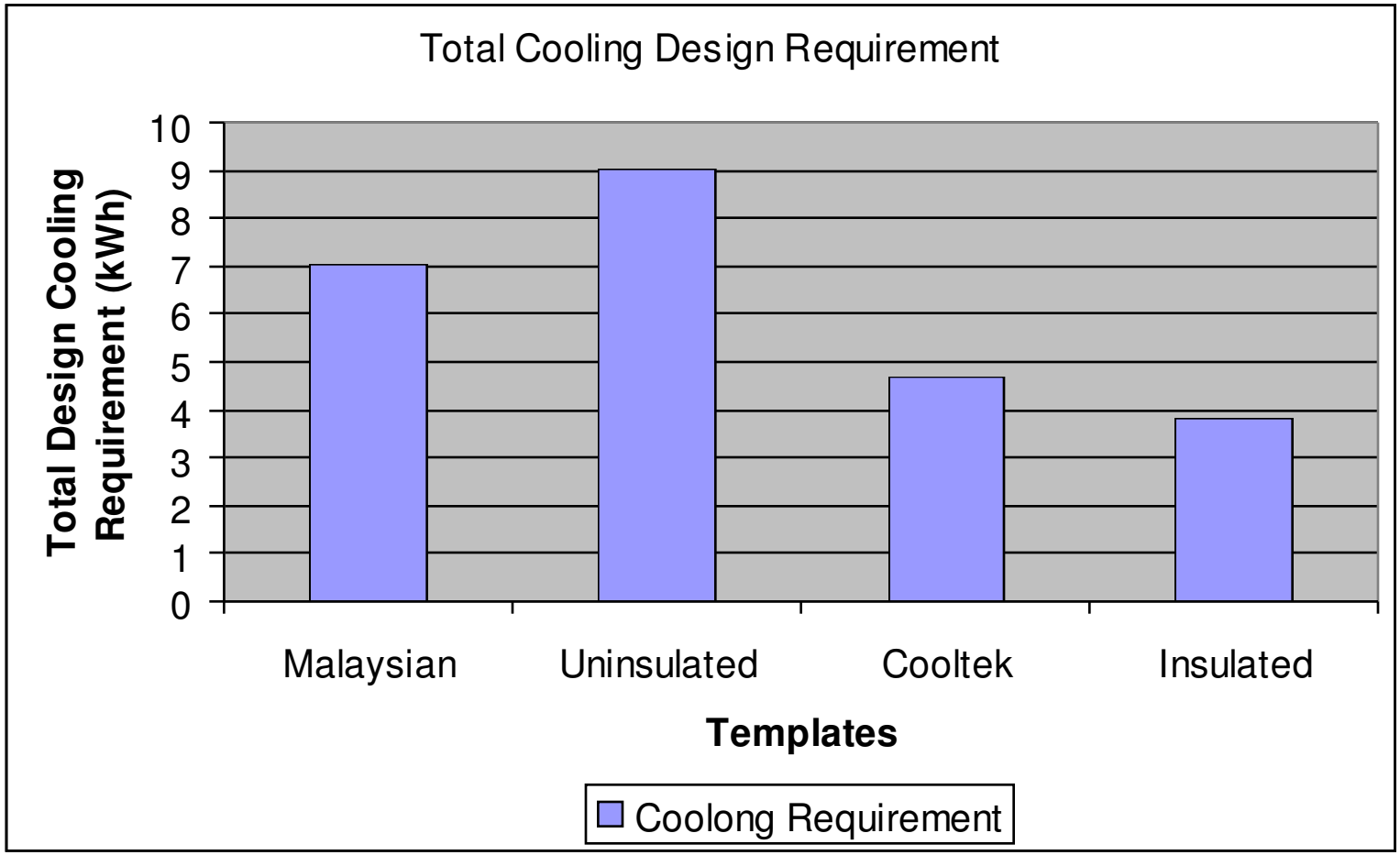


Figure 4.18: Cooling Design Requirement for terrace house with different insulating templates

Different Houses (Cont)

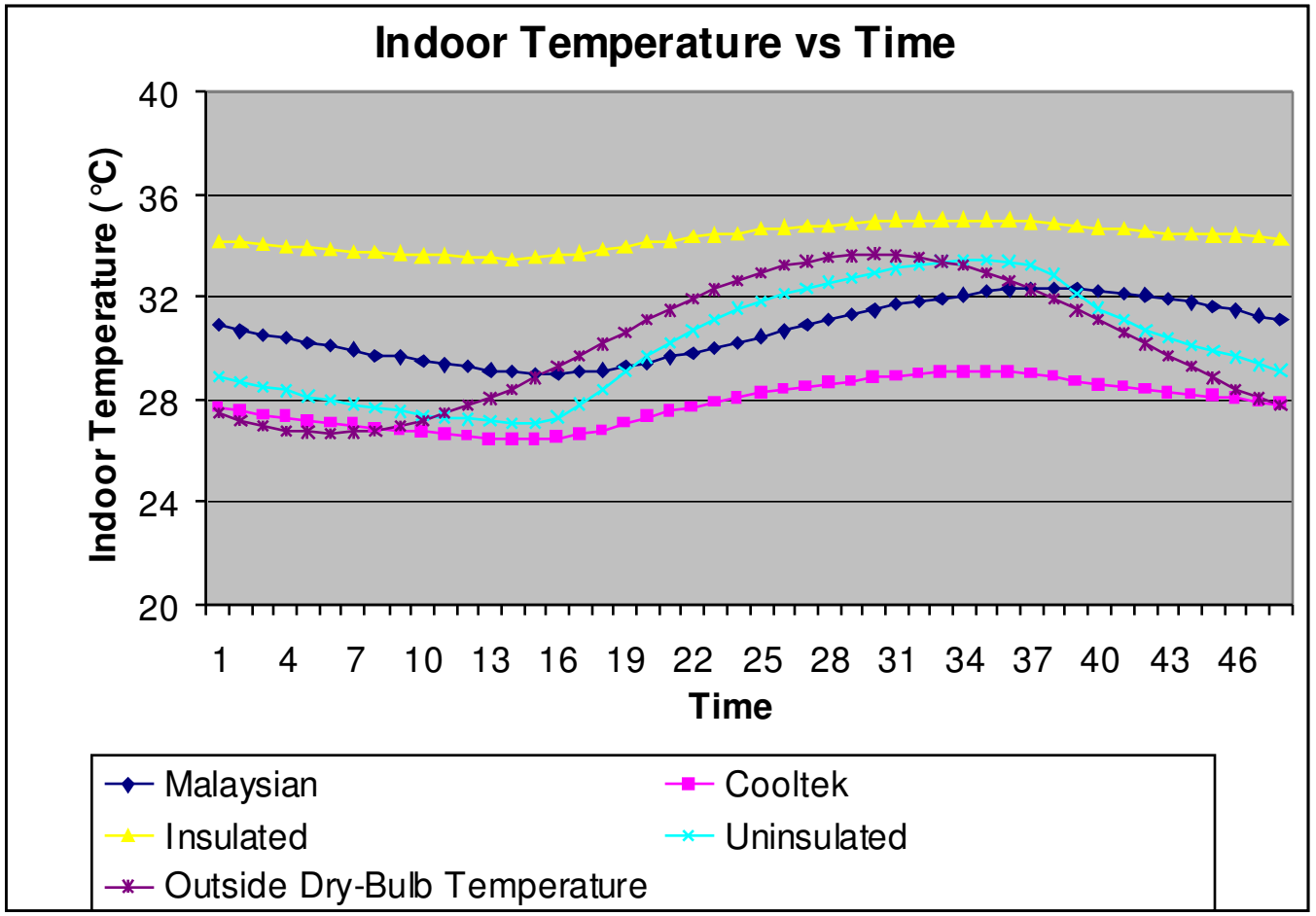


Figure 2.19: Indoor Temperature vs. Time for Cooltek house with different insulation templates

Different Houses (Cont)

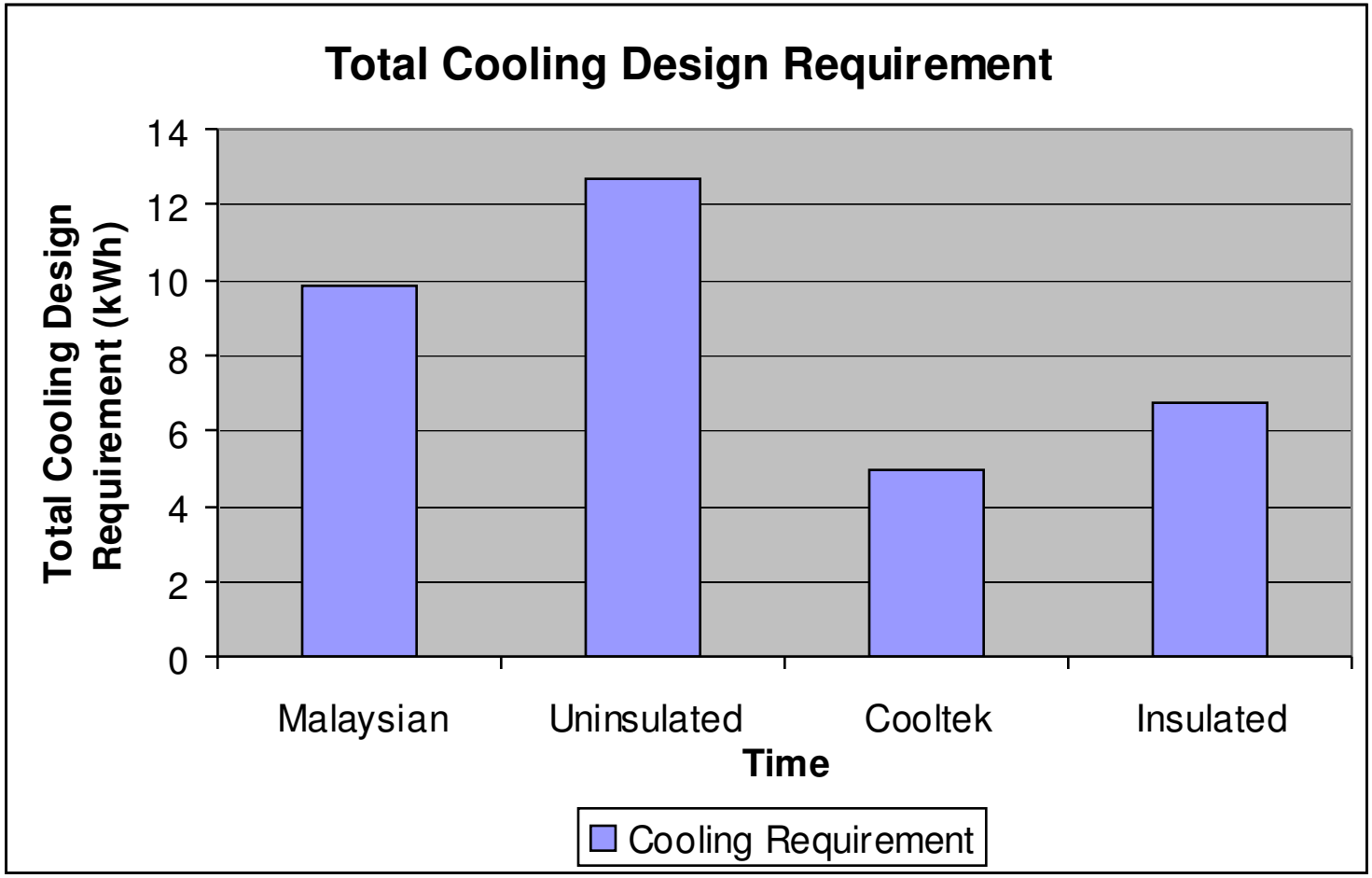


Figure 2.20: Cooling Design Requirement for Cooltek house with different insulating templates

Different Houses – Discussion

- The insulated house has a highest indoor temperature.
  - Greenhouse effect: Heat is prevented from leaving the house.
  - This shows that a totally insulated house would be sub-optimal without air conditioner or local weather condition.
- Insulated house requires the lowest cooling requirement 3.85kWh over un-insulated house 9.06 kWh.
  - This is because it keeps heat outside and maintain inside temperature easier. Saving up to RM1.30 of electricity bills everyday.
- The results of applying the insulation to different kinds of houses are quite similar.
  - Better insulated house have higher temperature with air condition turned OFF; lower cooling requirement to maintain the temperature with air conditioning turn ON.
  - The cooling requirement of 4.720kWh using the Cooltek template on terrace house means only RM1.235 per day is needed to maintain a temperature of 22℃ for the whole day.
  - The cooling requirement of 9.880kWh using Malaysian template on terrace house means RM2.47 per day is need.

Problems Encountered

- ECOTECT

- Floor - Ground Temperature

Summary

- Analysis of the simulation and design program used in this project.
- Simulation on terrace house subjected to different setup of walls, doors, roofs, ceiling and floors.
- Simulation of cooling load on different types of houses.

Conclusion

- It is proven that the cooling load of a typical Malaysian house can be improved with just a change of walls, doors and floors.
- Some parts can only be made by the developers while some can be made by the house owners.
- Whole community need a change of mindset to play a part to make this target a success.
- The changes is best applied together then to do it one by one.
- These improvements are not only applicable to terrace house. It is applicable to most residential units in Malaysia.
- Return of investment seems slow but might decrease if energy price rises.
- The benefits comes more in a long run as low energy usage also means less pollution and make the world a better place to live.

Recommendations

For further future research in this project, it is recommended that:

- More materials can be run in the simulation to find for better and cheaper materials.
- Other simulation program can be experimented as different programs have their own advantages.
- Simulations can be done on other kinds of buildings.
- Automated search for optimized operating points.

THANK YOU