Research title: Solar thermal energy heating of a glasshouse using phase change material (PCM) thermal storage techniques

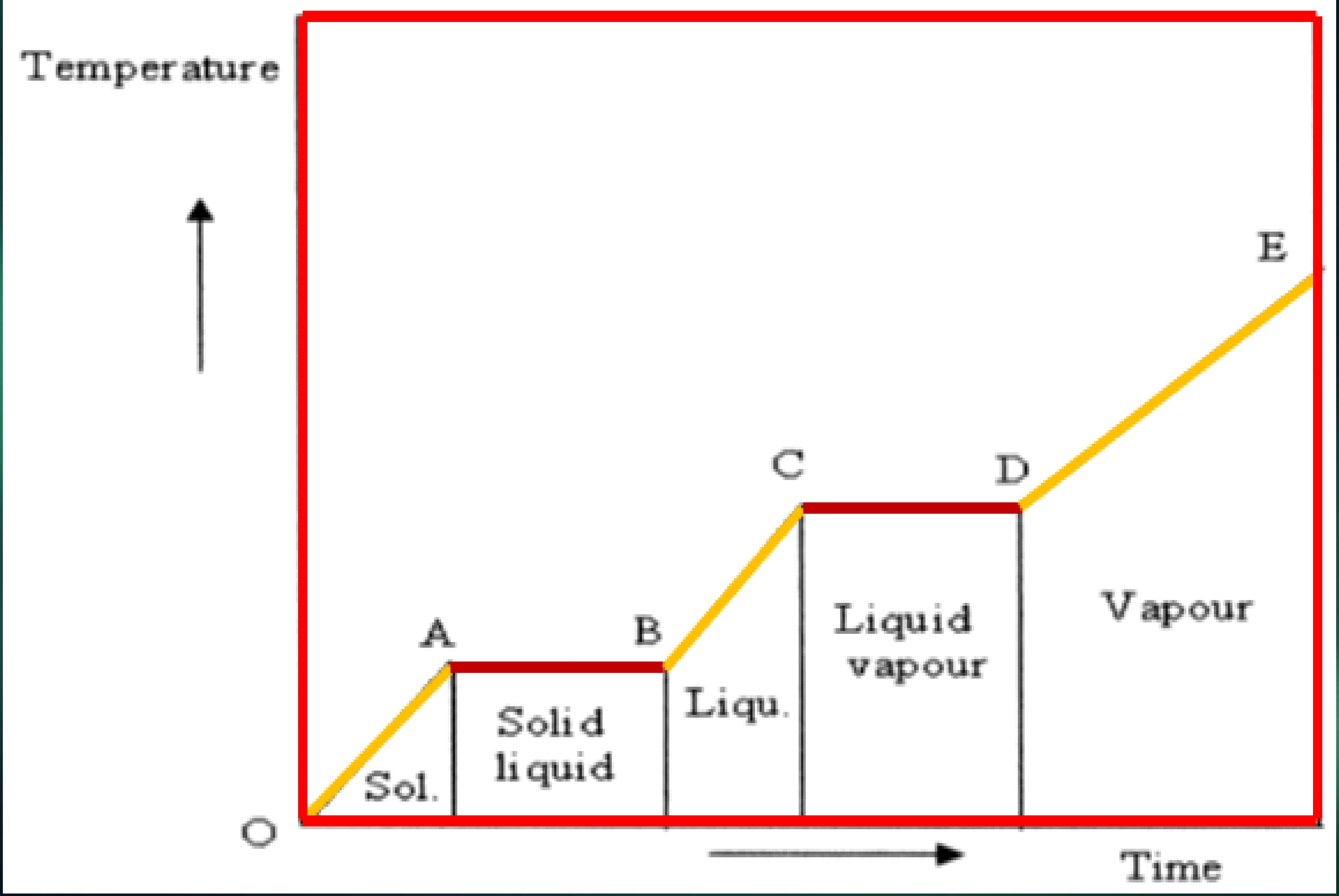
Research background

- The Royal Botanic Gardens (RBG) glasshouses heating at Kew Gardens
- Efficient and sustainable system that will save energy, cost, reduce CO_2 emission and improves plants condition
- One of the most prospective sources of energy is direct and indirect solar radiation

Background continue

- Reap and store this huge renewable sources of energy through thermal energy storage
- Thermal energy storage using phase change material (PCM)
- A substance can exist in three states namely: solid, liquid and gaseous depending on the pressure and temperature of the storage conditions.
- Two phases are commonly used in practice, solid and liquid

Two phases are commonly used in practice



Aim:

To design an efficient heating system that will use zero carbon emission energy to heat the tropical nursery glasshouse

Objectives of the research:

- To store enough solar energy to heat the glasshouse using PCM thermal storage technique
- To reduce CO2 emission to zero in the glasshouse heating
- Increase the heating system efficiency in the glasshouse and similar types
- Eliminate or reduce the use of fossil fuel to heat glasshouse and similar types

Objectives of the research continuation

- Improve the temperature fluctuation in the glasshouse by designing efficient ventilation system

- To improve plants growth condition

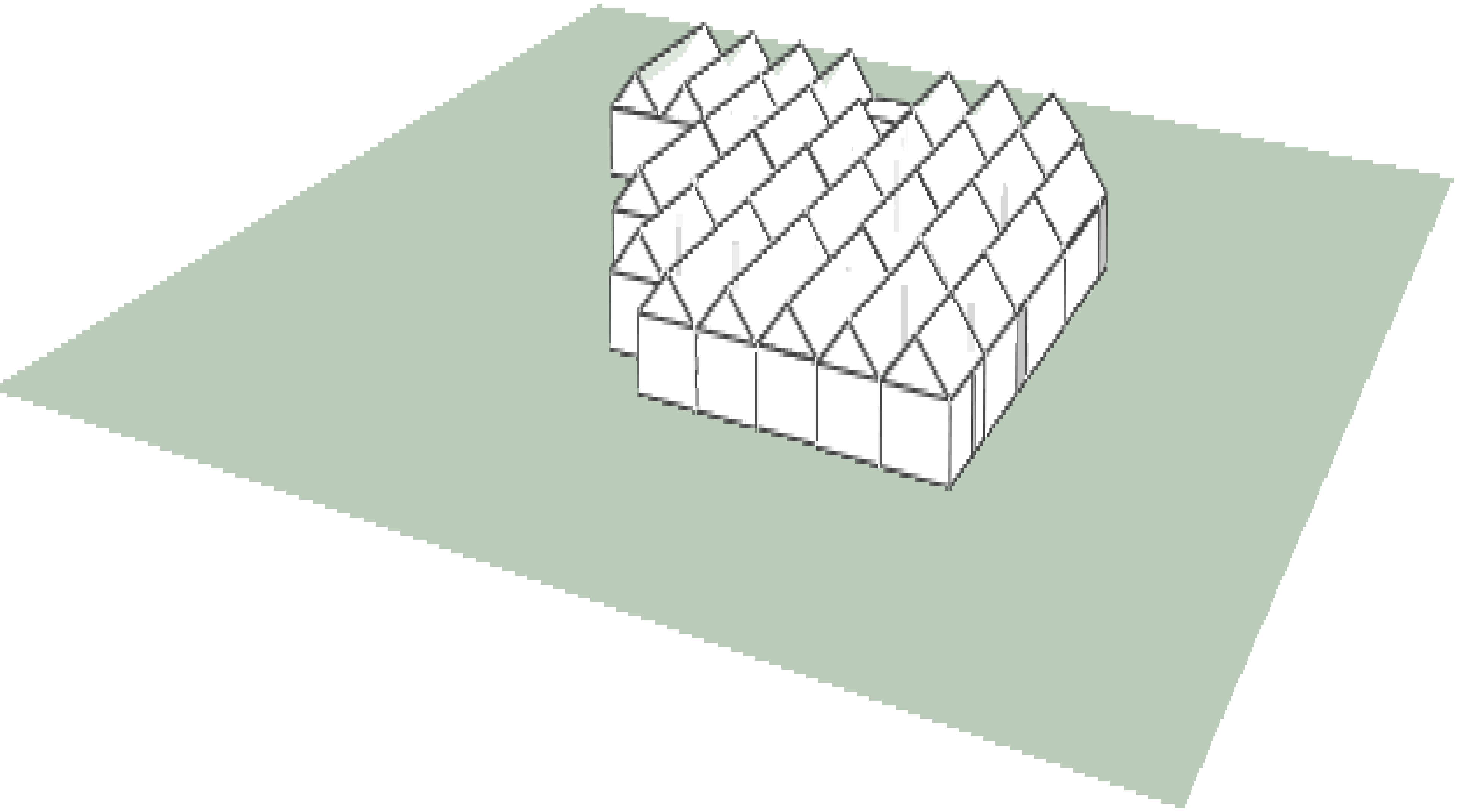
Research methodology

- Studied plants behaviour and characteristics to assist effective design of the glasshouse
- Investigate the design requirements and parameters of glasshouse
- Designed the glasshouse and determined the predicted thermal space conditioning energy requirement
- Detailed study of solar thermal collectors efficiency at various ambient temperatures and inlet hot water temperatures of the solar thermal system

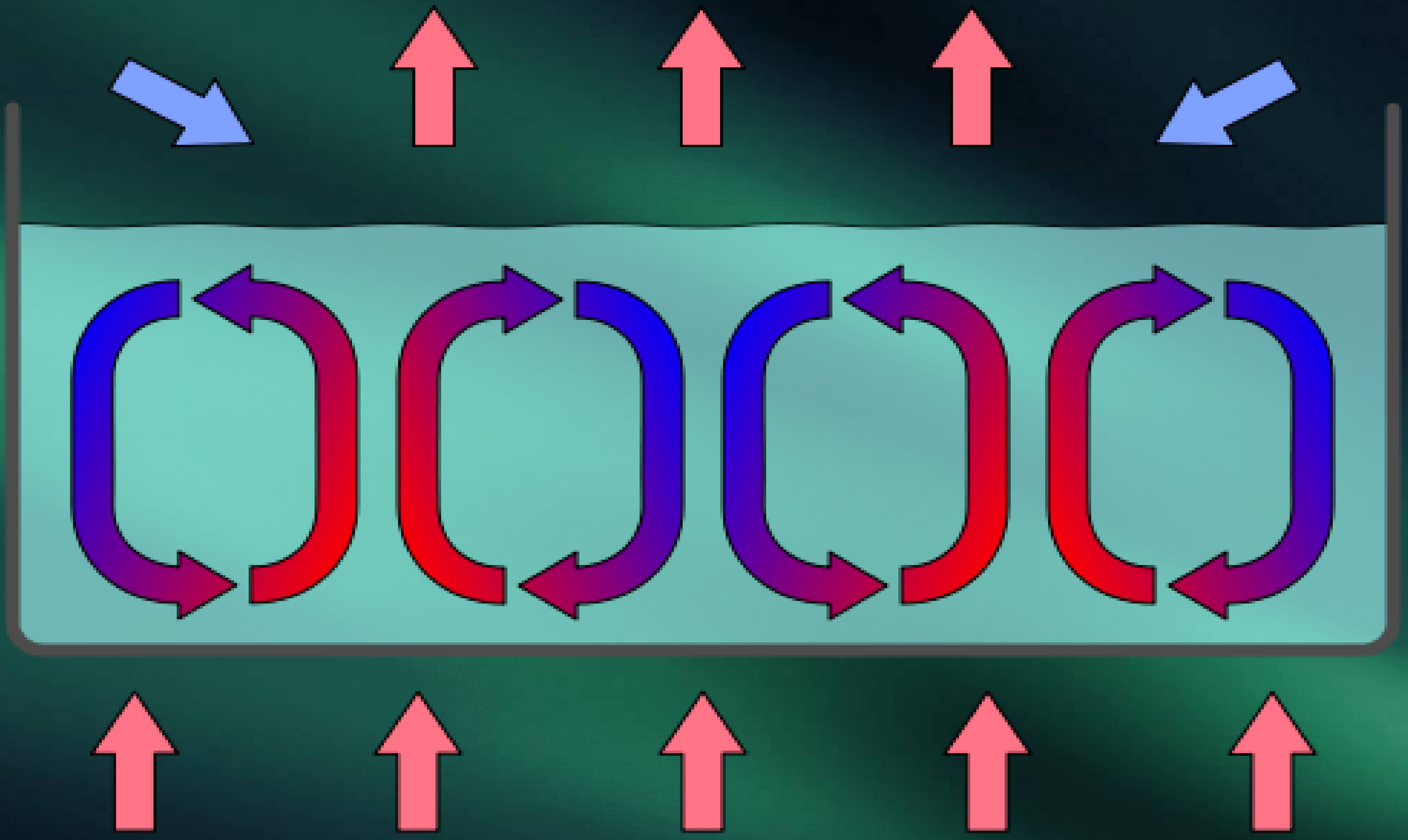
Research methodology continuation

- Selection of the appropriate solar collectors that will suit the application
- Estimation of thermal energy that can be delivered by the selected solar collectors
- Calculate solar thermal energy can be passively stored and effectively used in heating the space

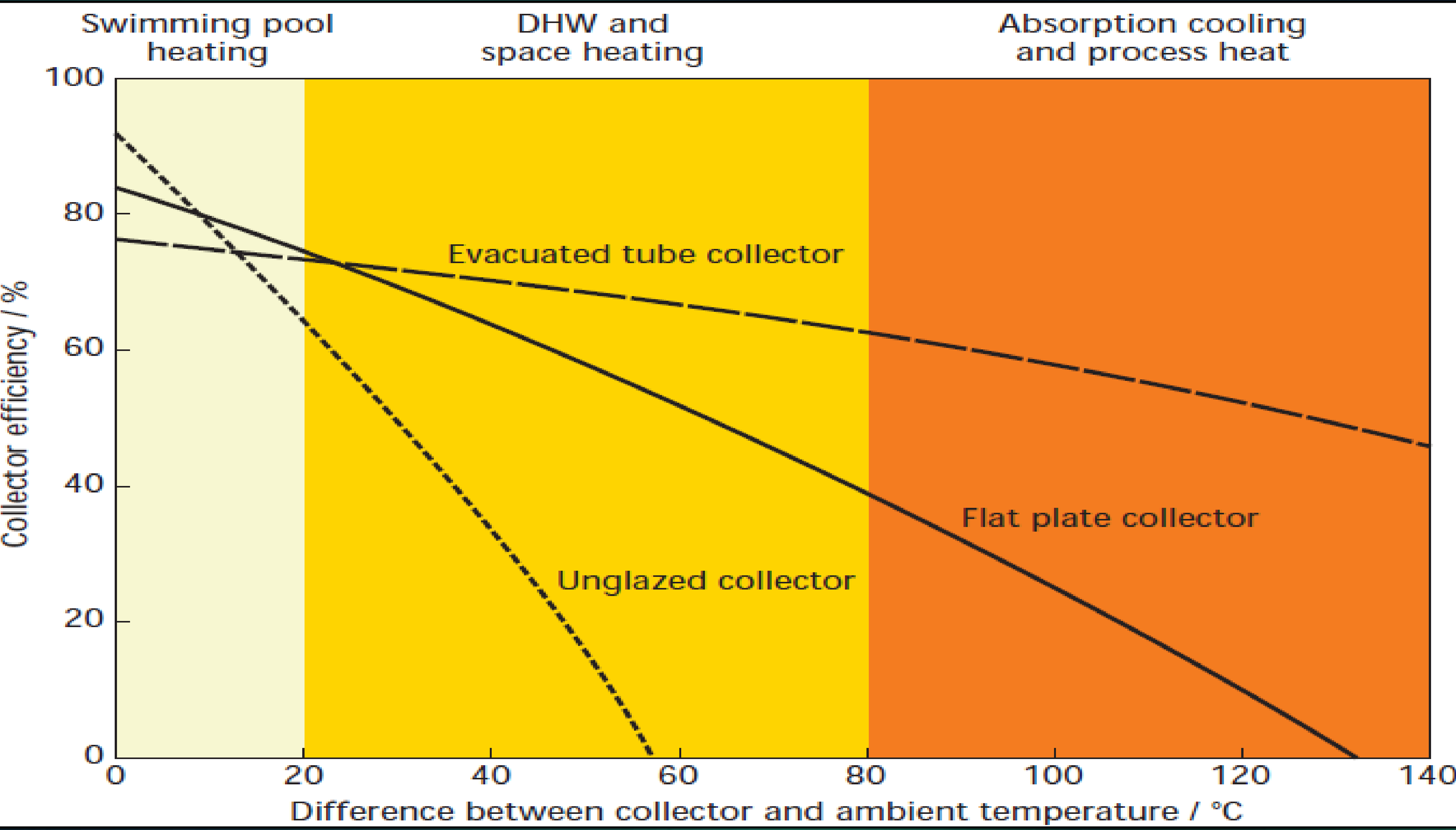
Glasshouse design



Convection cells in gravity field



Efficiency and temperature ranges for various types of collectors

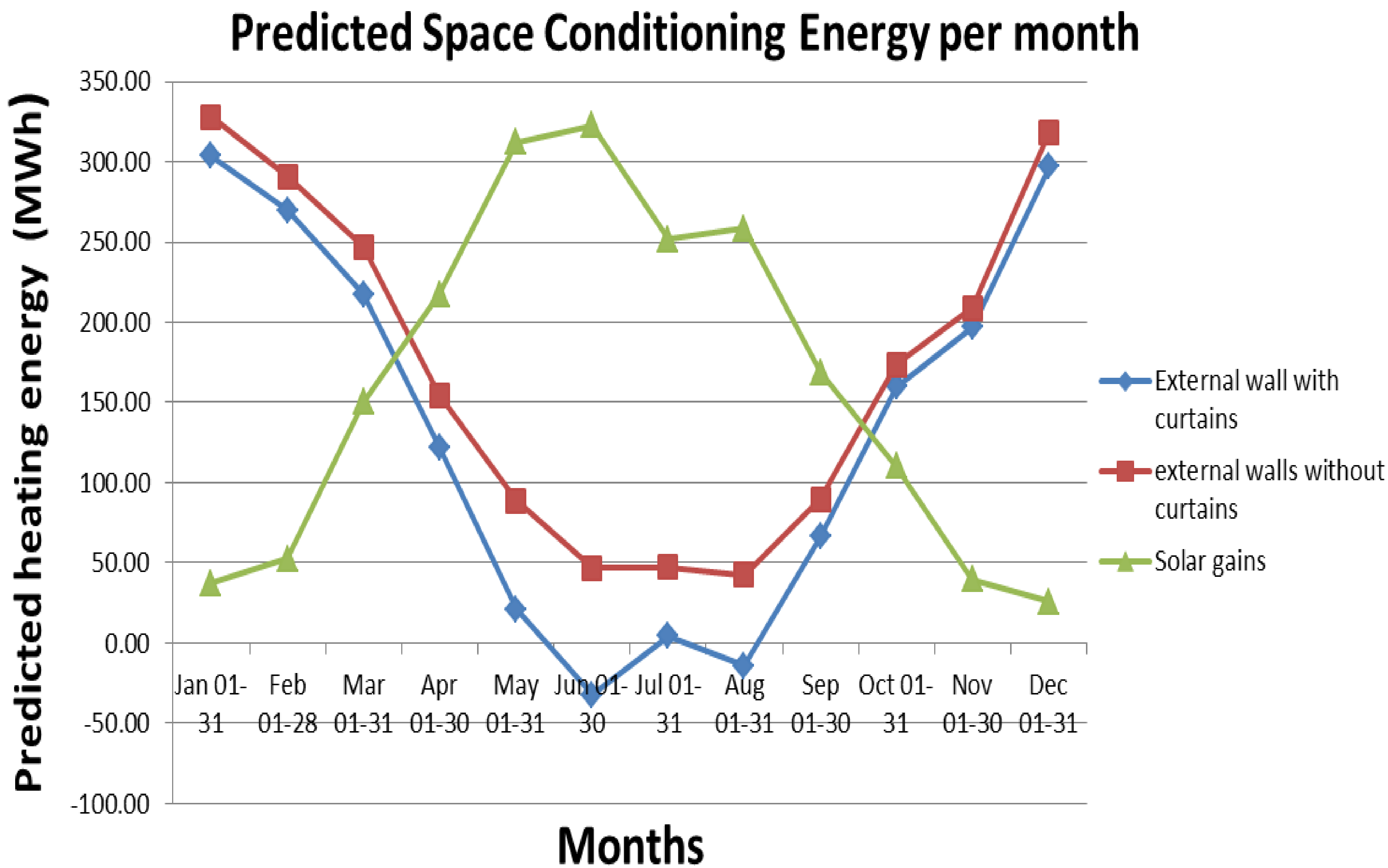


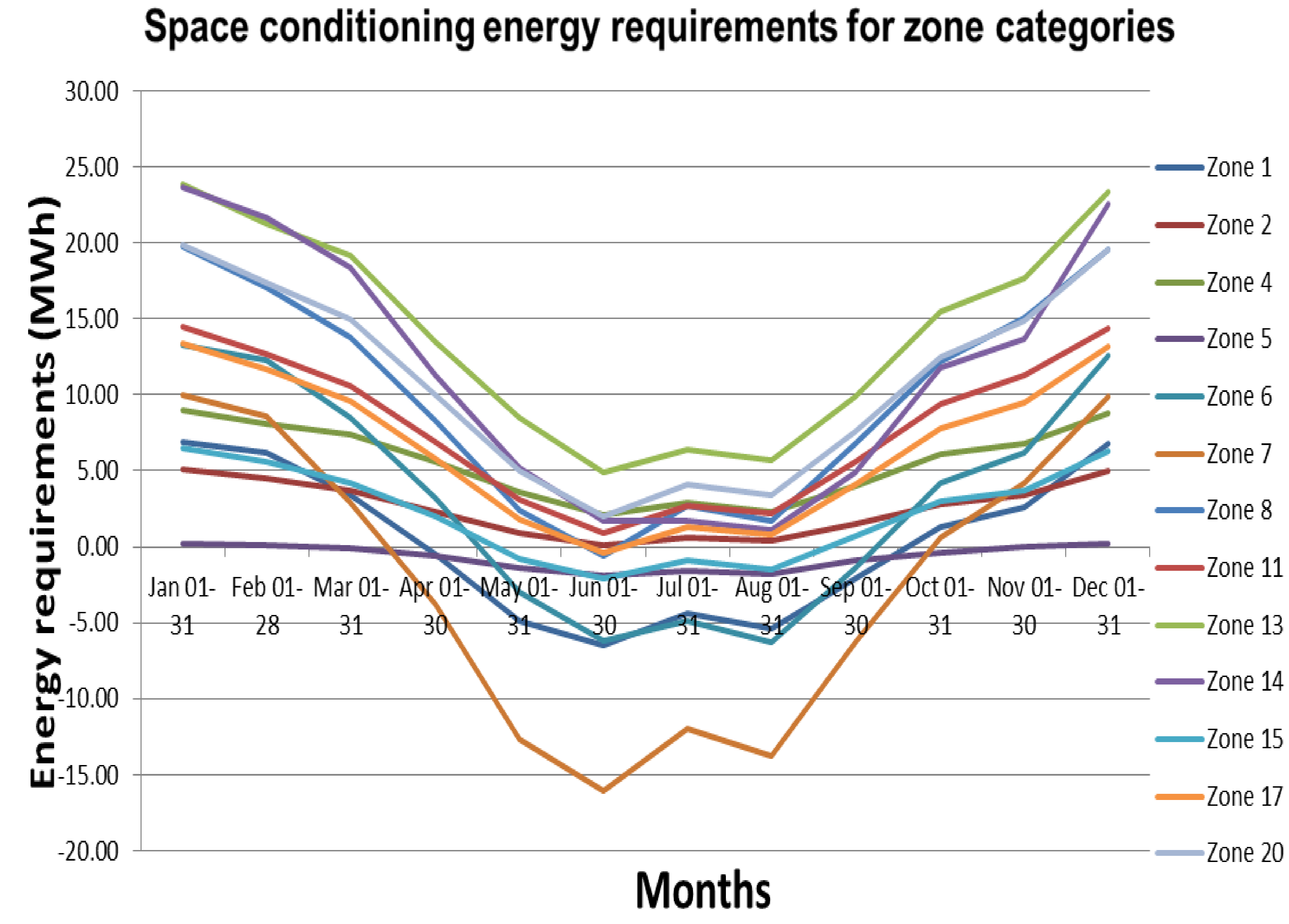
Source: CIBSE KS15

Preliminary results

- The glasshouse predicted space conditioning energy per year is1612MWh
- Delivered energy by Citrin, Agena and Thermomax collectors per year are 785, 779 and 681KWh respectively.
- Monthly space energy requirement and temperature profile of each zone determined
- Periods where thermal energy can be stored passively was determined

Energy requirements of the glasshouse with or without external wall curtains

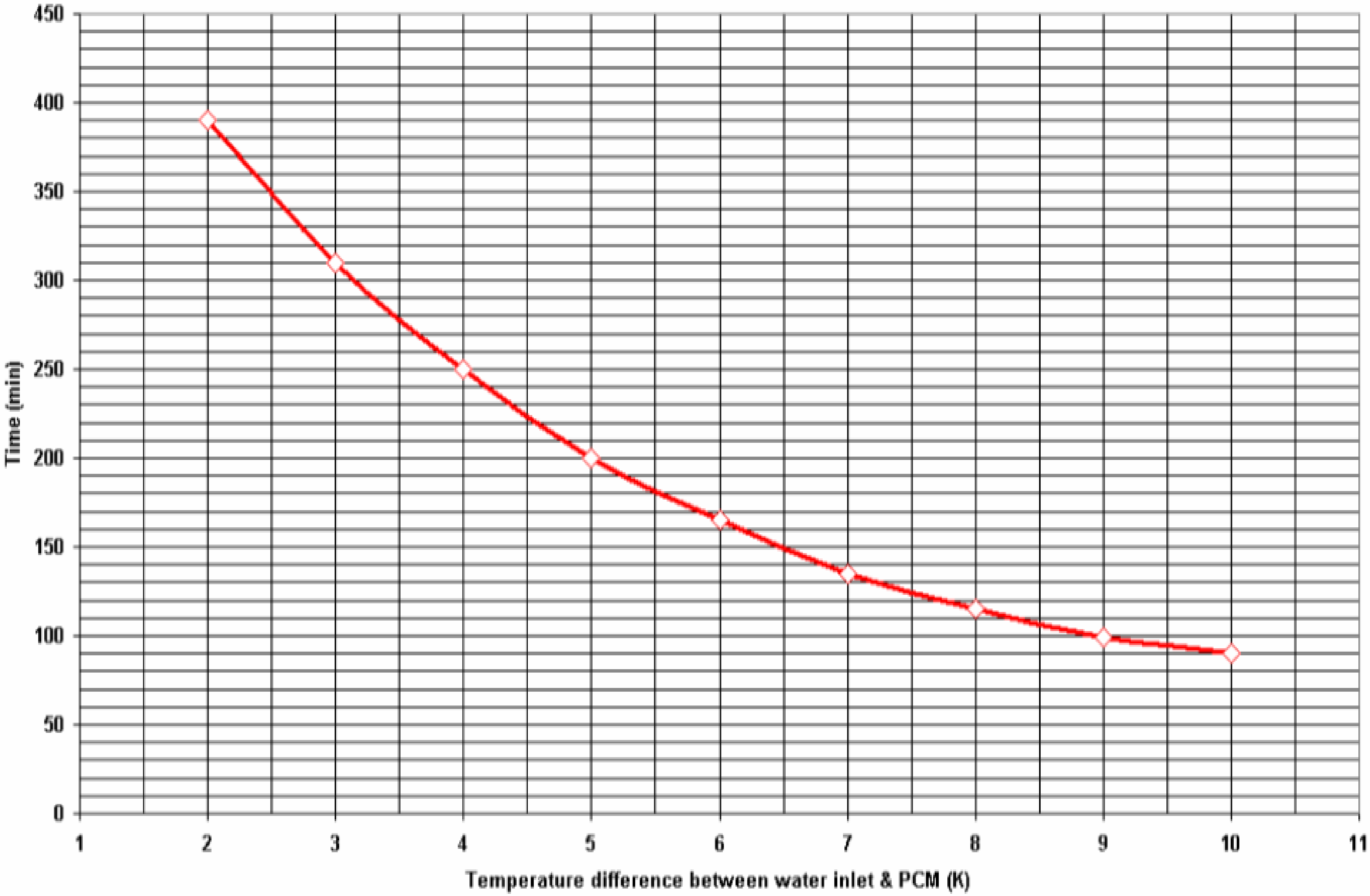




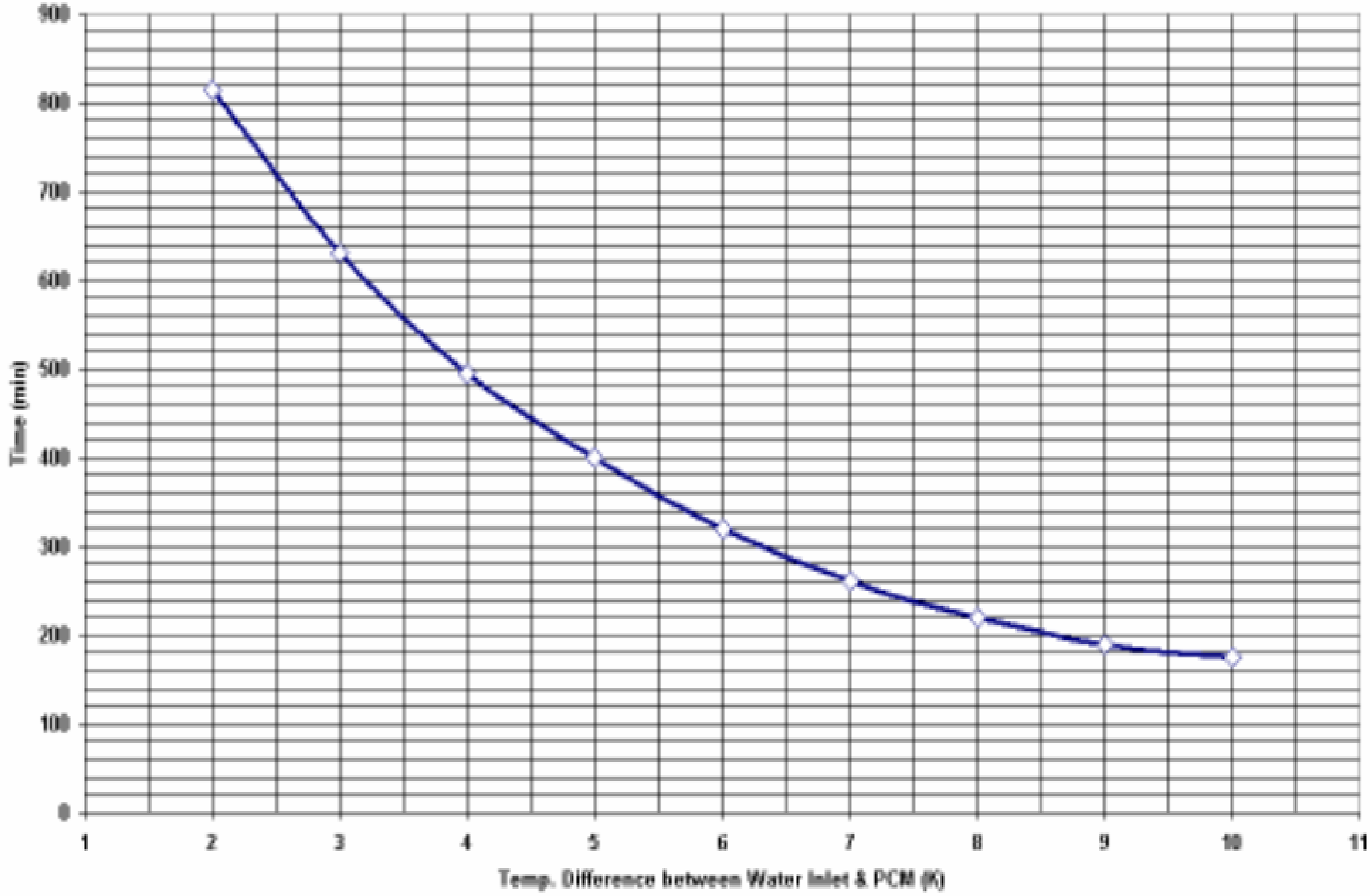
Space conditioning energy requirements for zone categories
Energy requirements (MWh)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
-10.00
-15.00
-20.00
Jan 01-31
Feb 01-28
Mar 01-31
Apr 01-30
May 01-31
Jun 01-30
Jul 01-31
Aug 01-31
Sep 01-30
Oct 01-31
Nov 01-30
Dec 01-31
Months
Zone 1
Zone 2
Zone 4
Zone 5
Zone 6
Zone 7
Zone 8
Zone 11
Zone 13
Zone 14
Zone 15
Zone 17
Zone 20

Thermal energy storage using PCM techniques

TubeICE melting profile

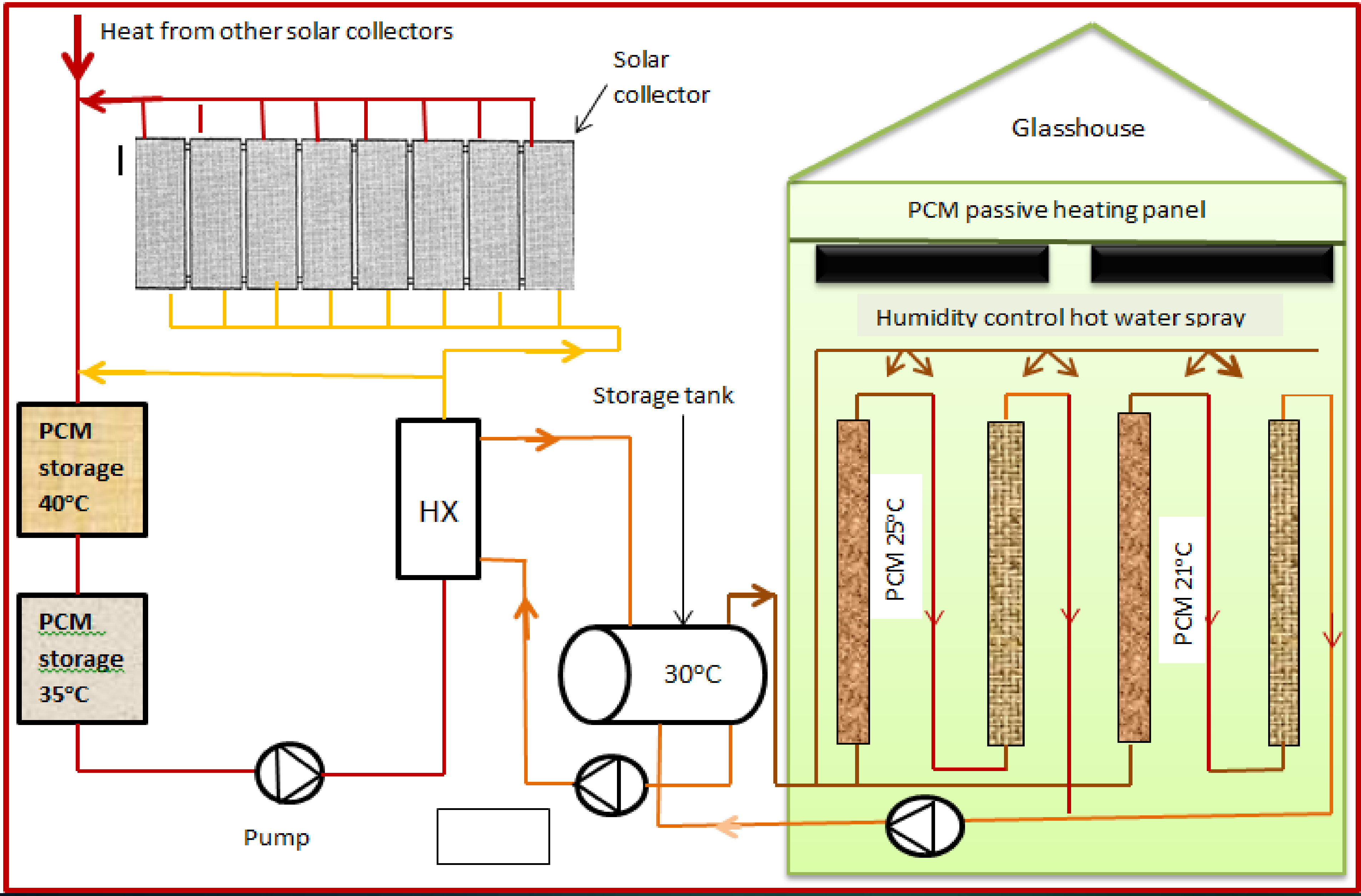


TubeICE freezing profile

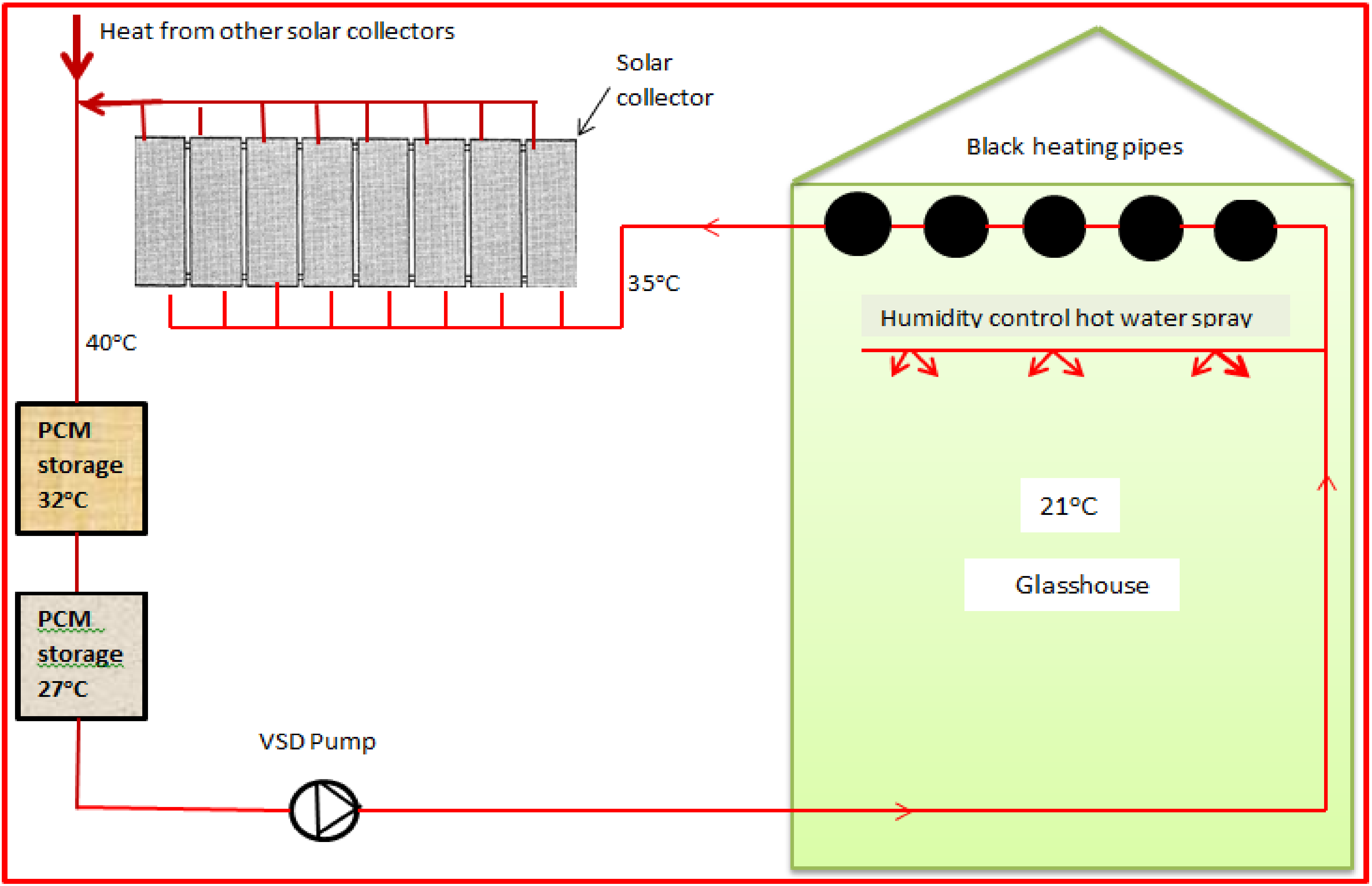


FlatICE PCM solution types

Proposed glasshouse heating system configuration



Proposed glasshouse heating system



Further research work to be done

- Calculate the amount of energy that can be stored in the PCM filled heating panels
- Calculate the amount of energy that can be absorbed by the black heating pipes
- How much energy can be generated by the passive systems
- How much energy will be required by the active systems
- Which of the two proposed systems is technically and economically viable