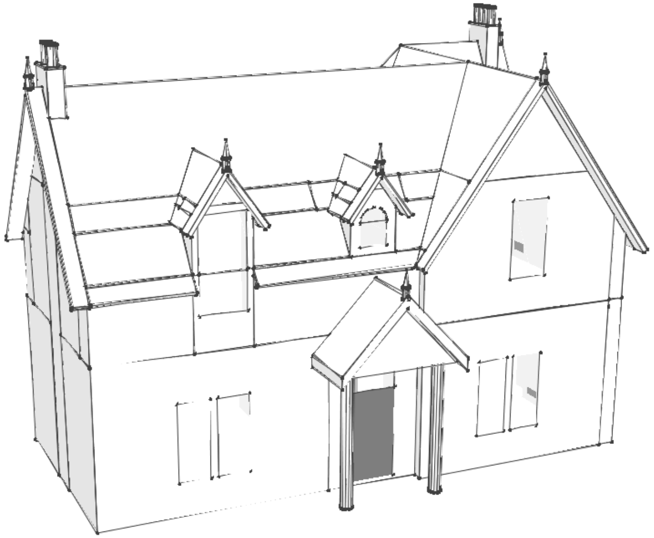


Thermal mass in traditional buildings

Dr Craig Wheatley

(Director IES Ltd.)

Thermal mass:

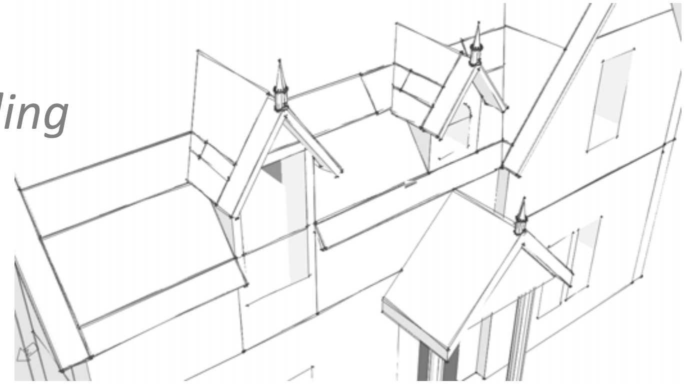
- **What is it? (***Why is it different to U-Values? / Seasonal effects?***)**
- **Lightweight versus heavyweight? (***What difference does it make?***)**
- **Benefits of thermal mass? (***What can it do for me?***)**
- **Thermal comfort (***How do we feel within Buildings?***)**
- **Benefits of thermal mass? (***How do I maximize the benefits?***)**
- **How can we investigate? (***Through dynamic thermal simulation***)**

Dynamic thermal simulation explained:

- **What is it? (***How does it work?***)**
- **What's required? (***What inputs do I need?***)**
- **Levels of detail? (***How can I improve accuracy?***)**
- **Results? (***How can I communicate?***)**

Energy case study: *Charleston Schoolhouse, Fife*

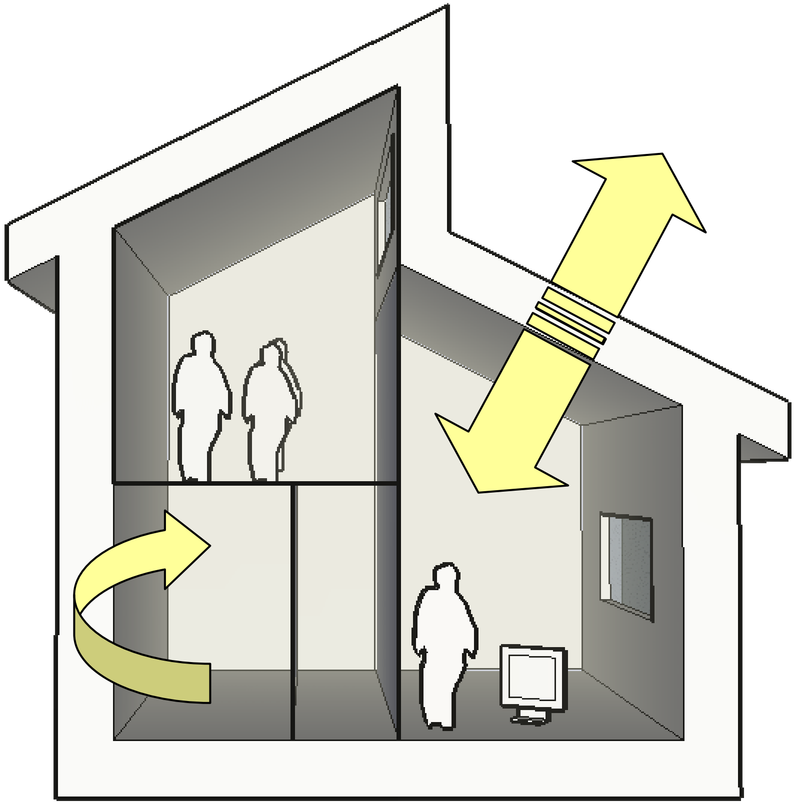
Thermal comfort case study: *Milton Wheelhouse, Stirling*



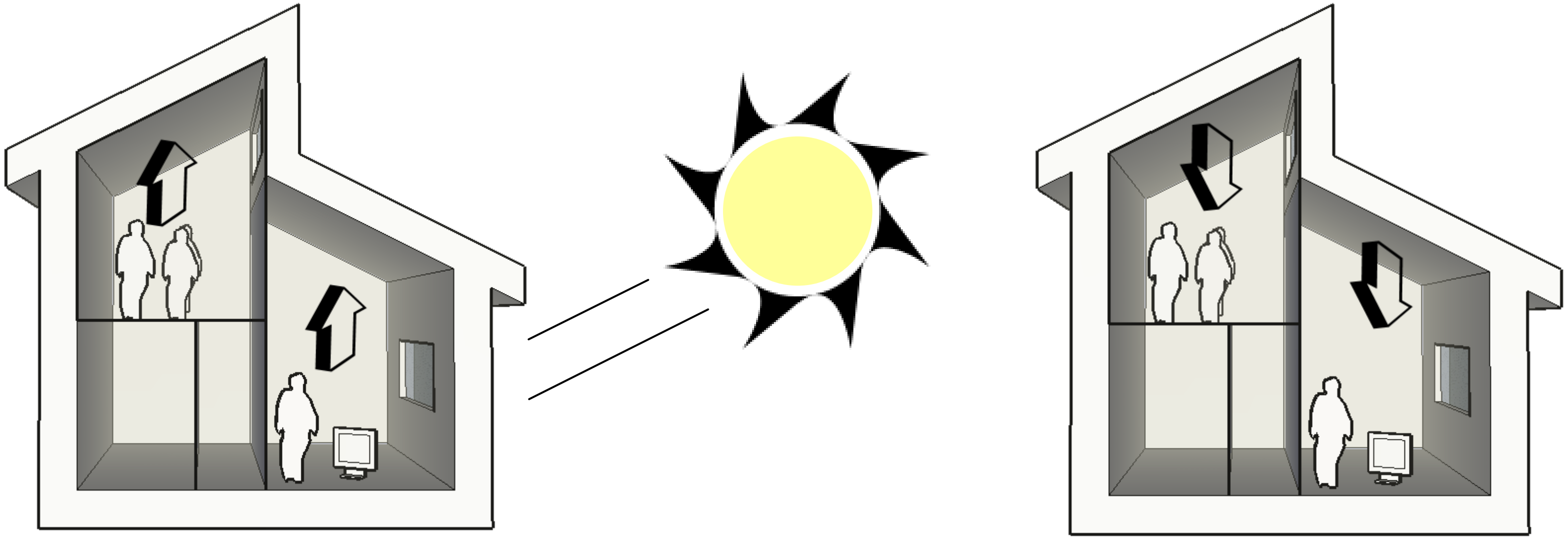
Thermal Mass, what is it? (*Why is it different to U-Values?*)

basic characteristic of materials with thermal mass is their ability to absorb heat/cool, store it, and at a later time release it.

U-value is the rate at which heat is lost / gained through a fabric



Thermal Mass, what happens seasonally? (*Winter*)

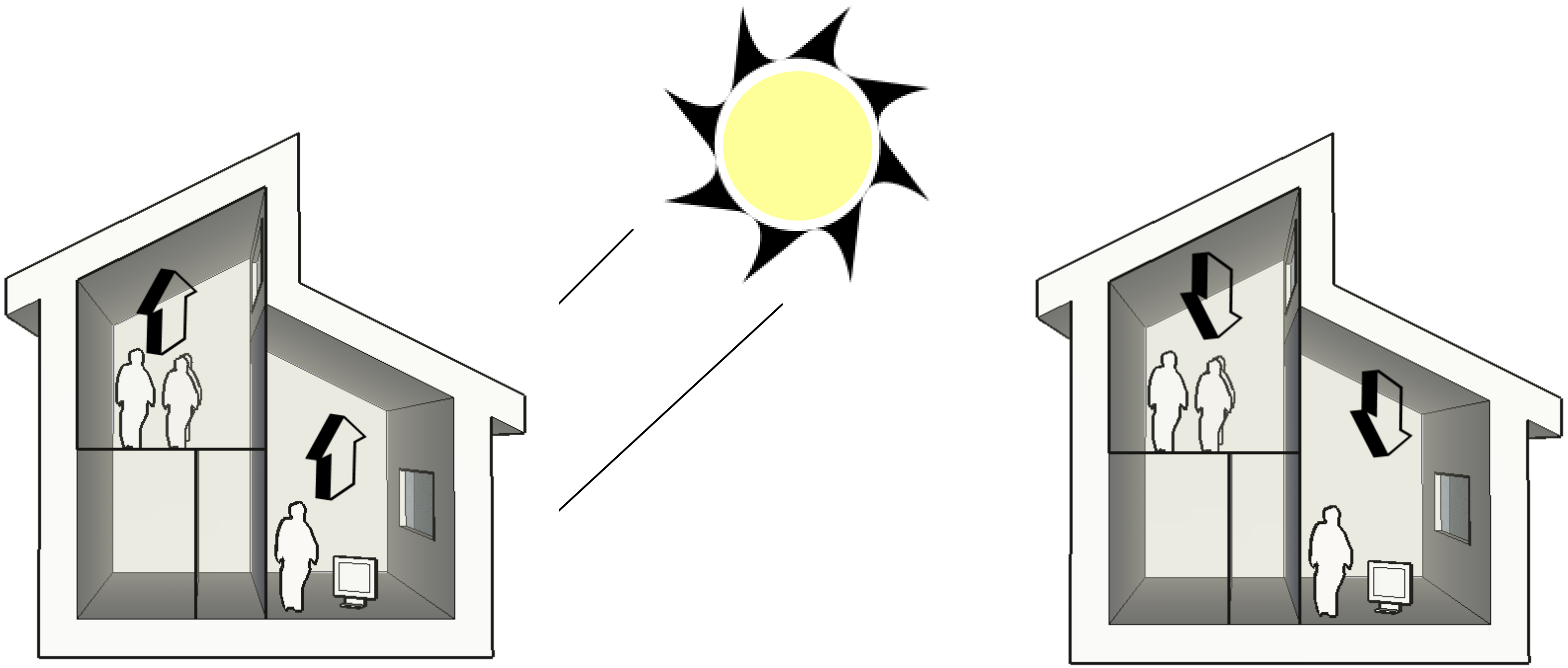


Winter - daytime *Winter – night-time*

absorbs internal/solar gains throughout day – releases heat during night

keeps internal temperatures higher reducing heating requirement next day

Thermal Mass, what happens seasonally? (*Summer*)



Summer - daytime *Summer – night-time*

absorbs internal/solar gains throughout day – releases heat during night

absorption of heat reduces internal temperatures; less cooling more comfortable

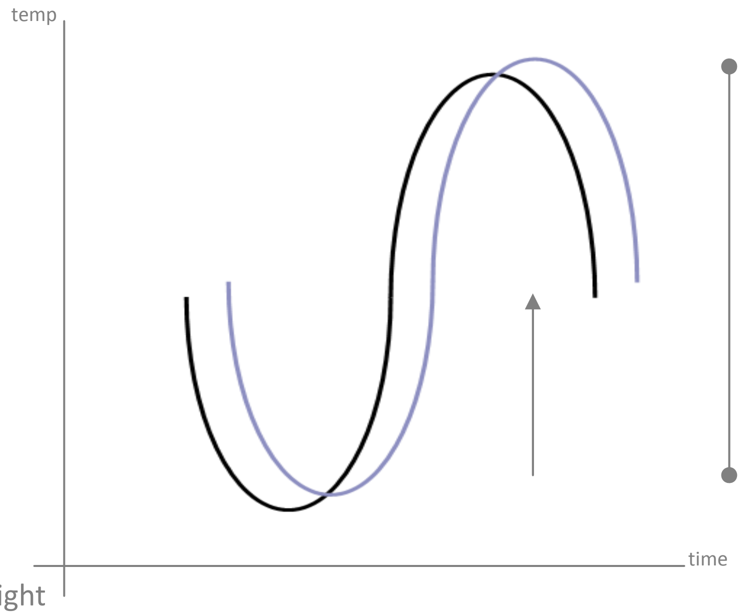
Lightweight versus heavyweight? (*What difference does it make?*)

key difference is amount of heat absorbed

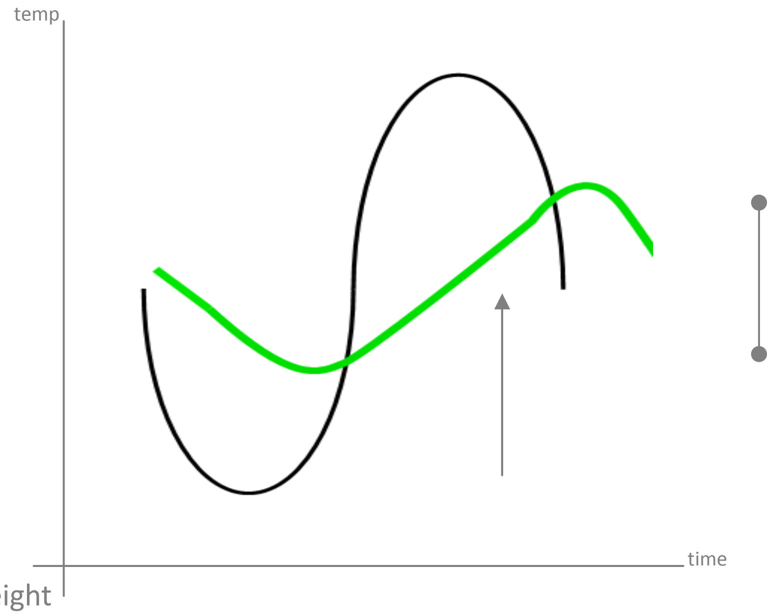
- heavyweight store a lot of heat so are said to have high thermal mass
- lightweight do not store much heat and have low thermal mass

resulting effect (*winter & summer*) is how responsive the internal conditions are to the climate

- heavyweight react slowly dampening internal temperature response
- lightweight react more quickly & follow external temperatures



lightweight



heavyweight

Benefits of thermal mass? (*What could it do for me?*)

US study* showed whole building energy savings of up to 18% (heating and cooling) and 8% (heating only) is possible when comparing lightweight buildings to heavyweight buildings

**Thermal Mass - Energy Savings Potential in Residential Buildings*
J. Kosny, T. Petrie, D. Gawin, P. Childs, A. Desjarlais, and J.Christian
© 2001 Oak Ridge National Labs

Australian study* showed total heating and cooling energy requirements can be reduced by 25% when comparing high thermal mass buildings to a homes with low thermal mass

**Thermal Mass INFO fact sheet Sustainable Energy Authority, Victoria*

UK study* showed insulation standard, ventilation strategy and orientation have consistent effects on heating energy requirements while the effect of thermal mass varies with insulation standard, climate and occupancy / gains scenario.

**Thermal Mass, Insulation And Ventilation In Sustainable Housing – An Investigation Across Climate And Occupancy*

Paul Tuohy1, Lori McElroy2 and Cameron Johnstone1
1ESRU, University of Strathclyde, Scotland
2 SUST, Lighthouse Building, Glasgow, Scotland

Thermal comfort (*How do we feel within Buildings?*)

UK study* showed thermal mass, ventilation, shading and shuttering are shown to have a large influence on summer peak temperatures with high thermal mass construction having a consistent beneficial effect.

**Thermal Mass, Insulation And Ventilation In Sustainable Housing – An Investigation Across Climate And Occupancy*

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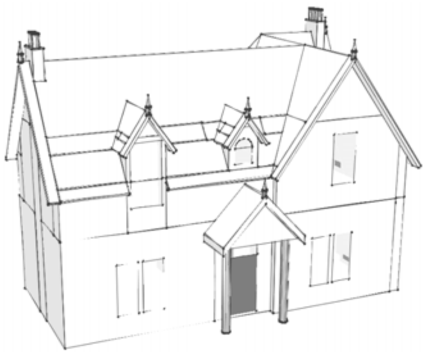
Radiant temperature

Thermal radiation is the heat that radiates from a warm object.

Radiant temperature has a greater influence* than air temperature on how we lose or gain heat to the environment. Our skin absorbs almost as much radiant energy as a matt black object.

**Workplace health, safety and welfare*

Health and Safety Executive
www.hse.gov.uk/temperature/thermal



Benefits of thermal mass? (*How do I maximize the benefits?*)

Winter:

soaking up 'free' heat will maximise the reduction in heating energy

good solar access is important

occupied during the day

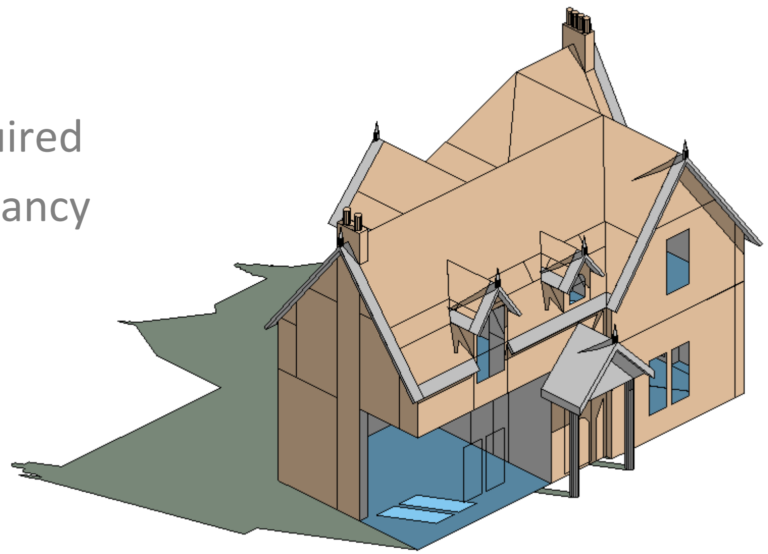
without this the addition of thermal mass can increase winter heating

Summer:

removal of absorbed heat is key

night-time ventilation / flushing required

not necessarily suited to 24 hr occupancy

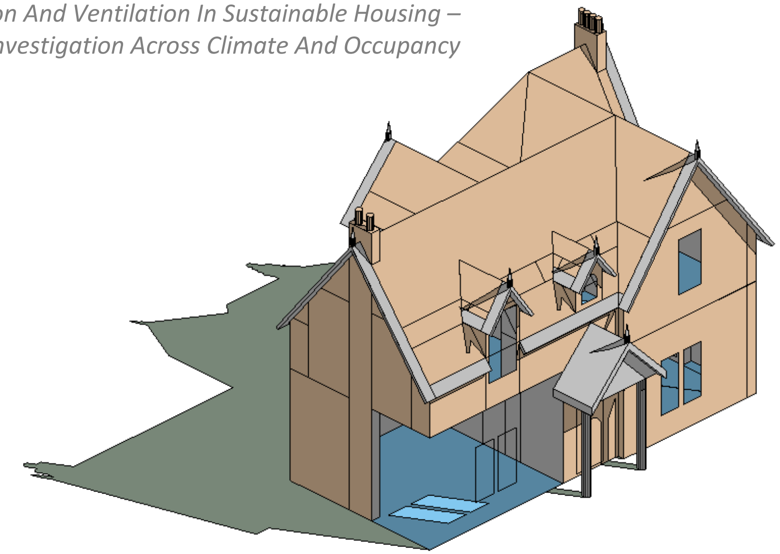


…often part of a holistic approach

Benefits of thermal mass? (*How do I maximize the benefits?*)

UK climate region	Building Reg's	Type of construction indicated by 'Vales room' with 100% convective heat delivery and ideal control (Heating (H) or Cooling (C) benefit in brackets)			
North	0.3	Low mass (H)	Either	High mass (C)	High mass (H,C)
	0.1	Low mass (H)	Either	High mass (H,C)	High mass (H,C)
South	0.3	Either	High mass (C)	High mass (H,C)	High mass (H,C)
	0.1	Either	High mass (H,C)	High mass (H,C)	High mass (H,C)
Occupancy / Gains Scenario		Very Low	Low	Standard	High

**Thermal Mass, Insulation And Ventilation In Sustainable Housing – An Investigation Across Climate And Occupancy*

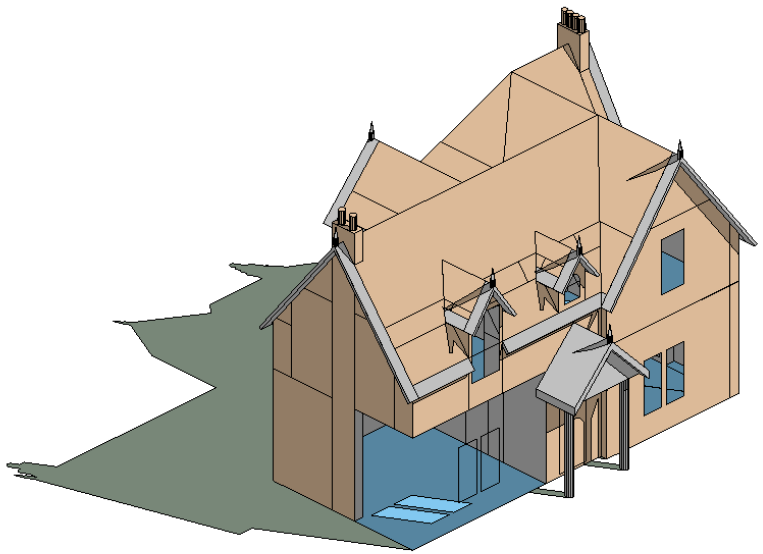


…often part of a holistic approach

Benefits of thermal mass? (*How do I maximize the benefits?*)

improved efficiency of a central heating boiler (control):

- high thermal mass favors small boilers working at maximum output & *therefore* efficiency, longer period of operation at lower output, longer periods inactive
- buildings a low thermal mass, tend to have much wider changes in temperature, and the boiler can cycle on and off constantly



…often part of a holistic approach

Benefits of thermal mass? (*How do I maximize the benefits?*)

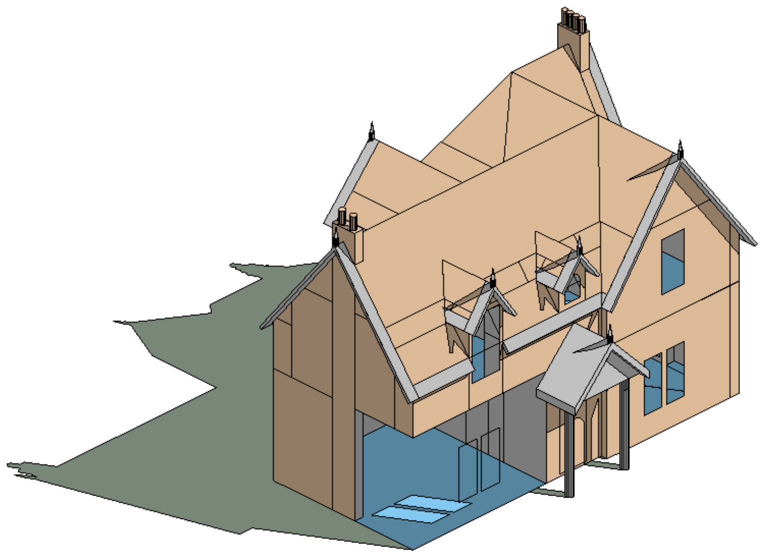
as a rule of thumb the best place for thermal mass is ***inside*** the insulated building envelope

a better insulated envelope will mean more effective thermal mass

ideally thermal mass should be left exposed internally to allow it to interact with the house interior

- however plaster adds thermal mass to walls
- use quarry tiles, etc. on concrete slab/suspended floors
- avoid covering thermal mass with carpets,

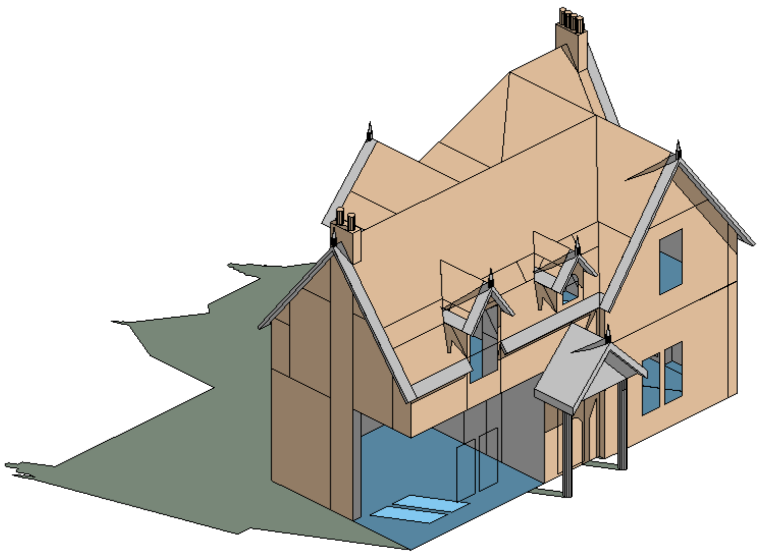
…often part of a holistic approach



How can we investigate thermal mass? (*Energy simulation*)

thermal mass can only be investigated using simulation techniques that can take dynamic thermal effects into consideration

- steady state approaches not valid
- dynamic thermal simulation most appropriate (*examples*)
  - IES Apache / EDSL TAS / US DoE Energy Plus



Dynamic thermal simulation: **What is it? (*How does it work?*)**

"Virtual" representation of a Building project

simulates the Building operation for a period of time (*typically annual*)

uses climate data: 8760 data points (*each hour of the year*)

inc Air temperature

Cloud Cover

Solar radiation (direct and diffuse)

Wind speed and direction

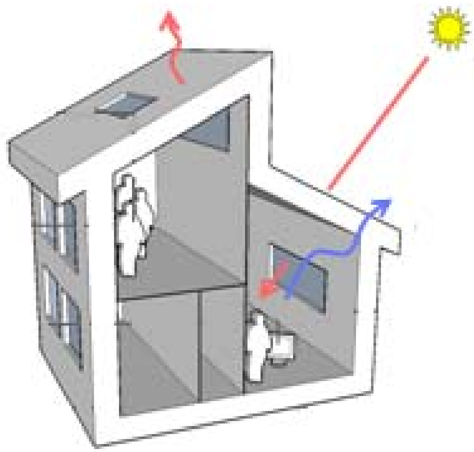
Solar azimuth & altitude (*etc*)

energy use is calculated through assessment of

Desired Building operation (set-points)

climate gains/losses

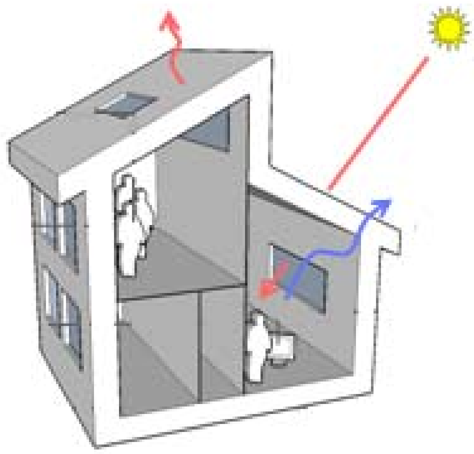
internal gains



accounts for dynamic effects such as *Thermal Mass*

Energy simulation: What's required? (*What inputs do I need?*)

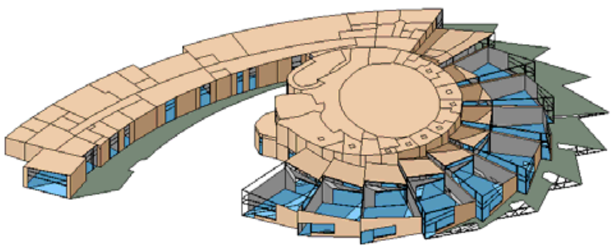
- ✓ location – *Juneau, Alaska will perform differently to Jaipur, India*
- ✓ orientation – *how does the sun moves around the building*
- ✓ Building Type: - *how is the building used?*
  - occupancy / lighting / equipment usage
  - heating / cooling set-points
- ✓ HVAC equipment – *how is the building heated / cooled?*
- ✓ Building Constructions – *how does the building protect against climate?*



Energy simulation: Levels of detail? (*How can I improve accuracy?*)

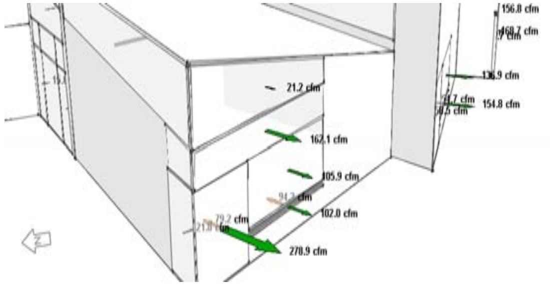
Energy simulations vary in capability simulations can be improved by including:

Solar & Daylight penetration – solar gain assessed at the surface
Daylight sensors
Share annual lighting simulation data with energy model
Wind / Stack driven natural ventilation effects
Pressure driven internal air flow



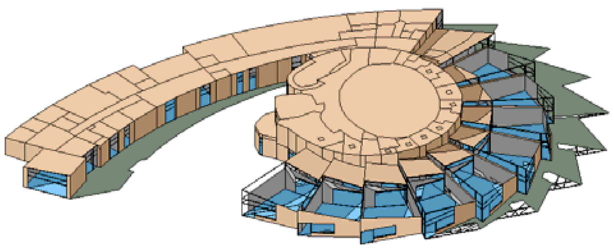
Solar penetration

Daylight sensors



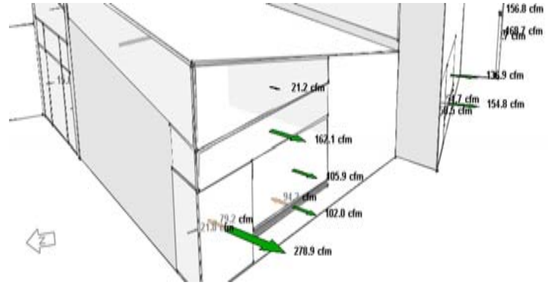
Wind / Stack

Energy simulation: Results? (*How can I communicate?*)

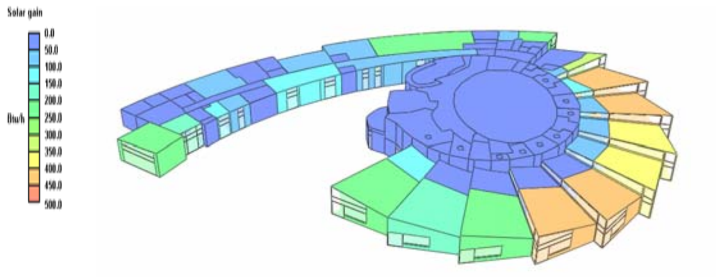


Solar penetration

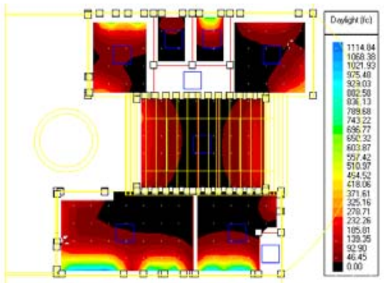
Daylight levels



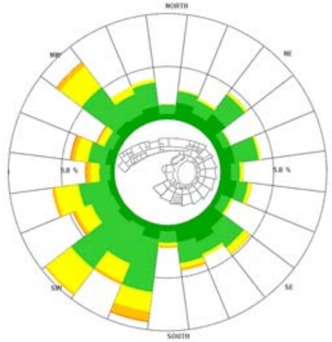
Natural Ventilation



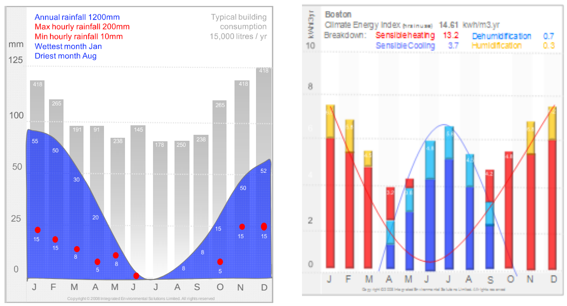
Results colour coded on model



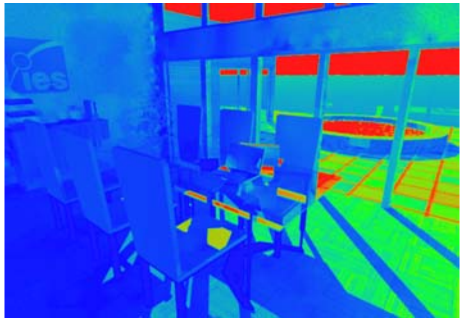
Daylight Metrics



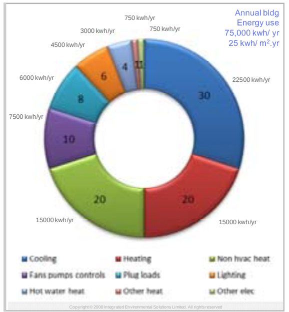
Climate Understanding



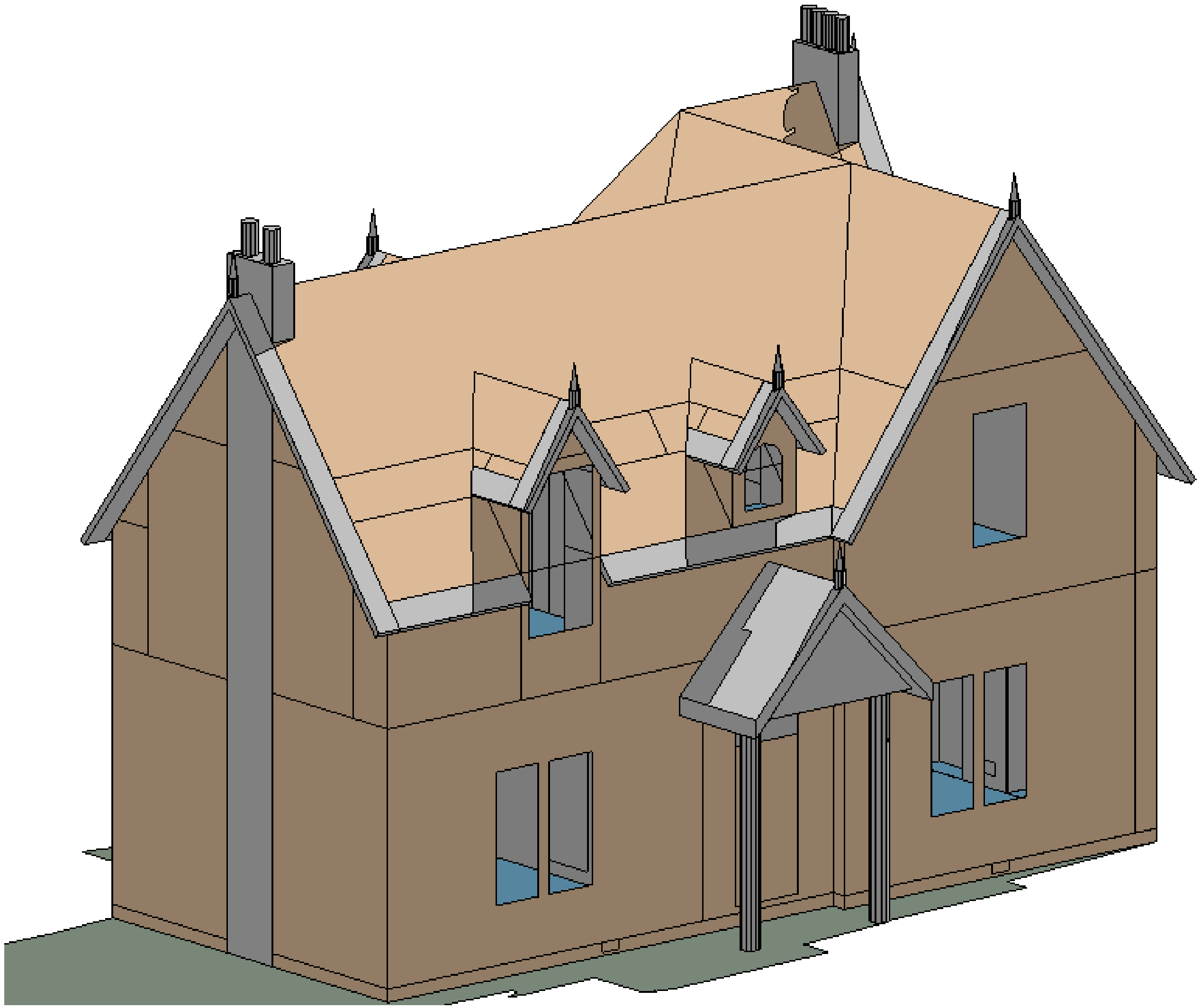
Monthly Energy Output*



Daylight contours

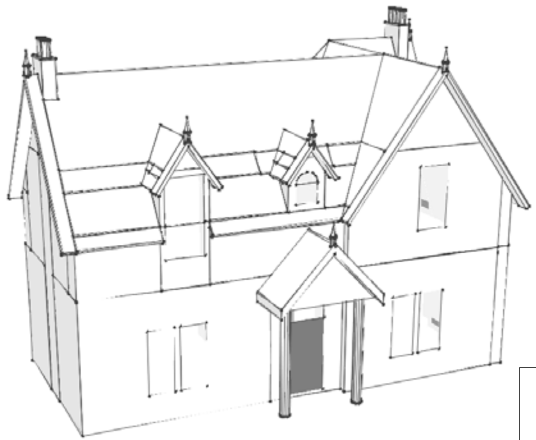


Annual Energy Output*

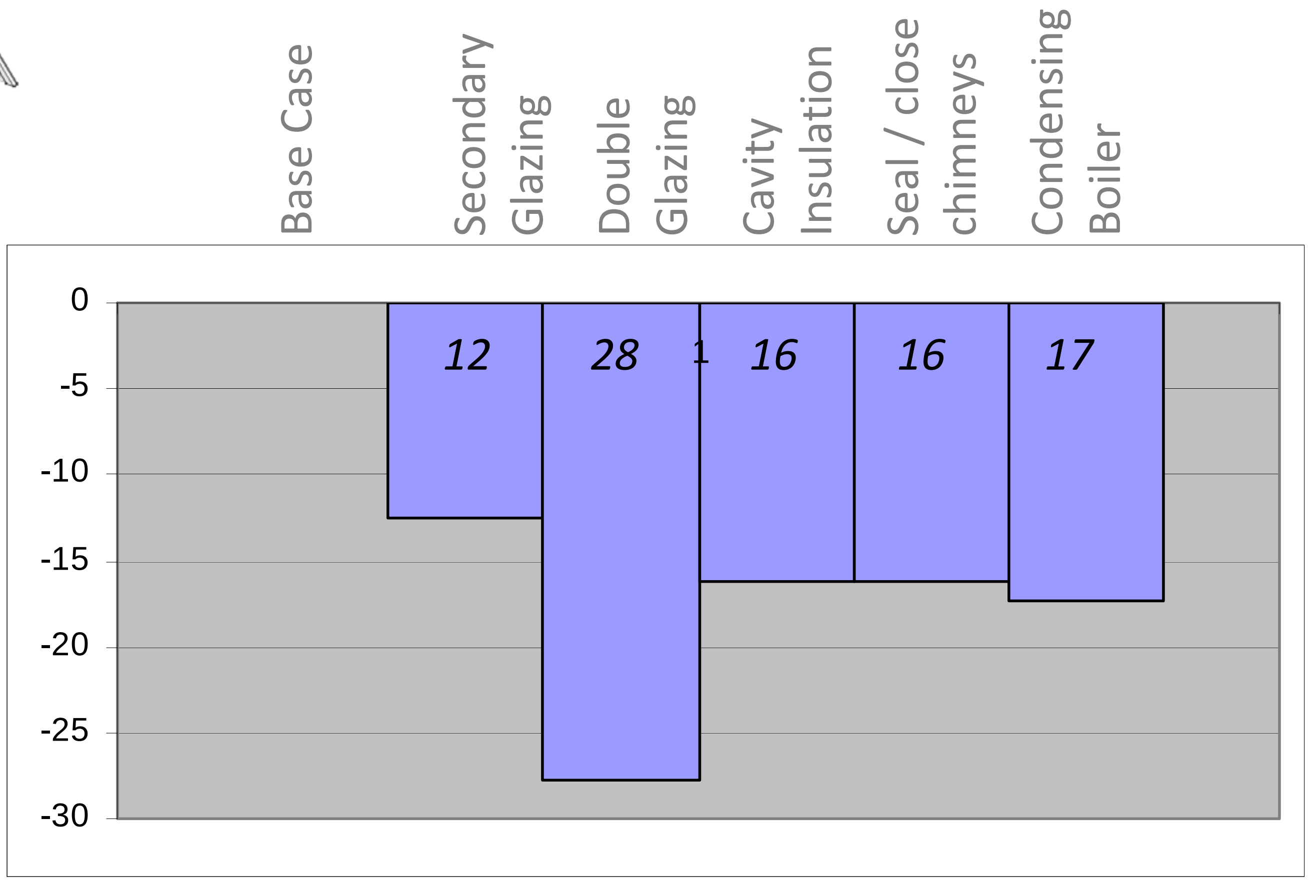


Preliminary energy case study

Charleston Schoolhouse, Fife



% energy reduction



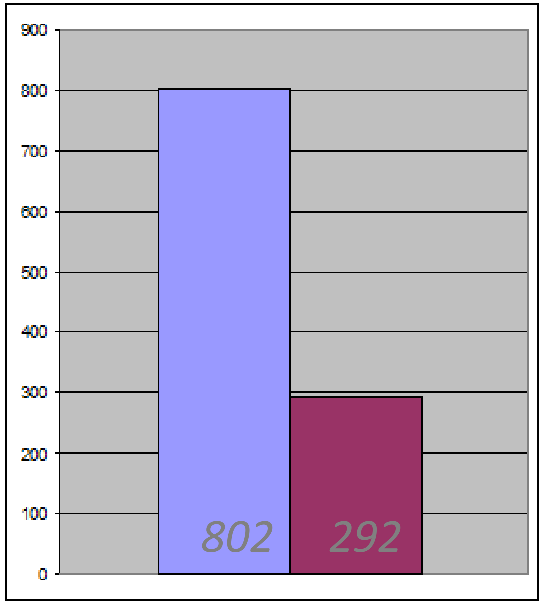
combinations still to be assessed
combinations not cumulative

Preliminary energy case study

Charleston Schoolhouse, Fife

Thermal comfort case study

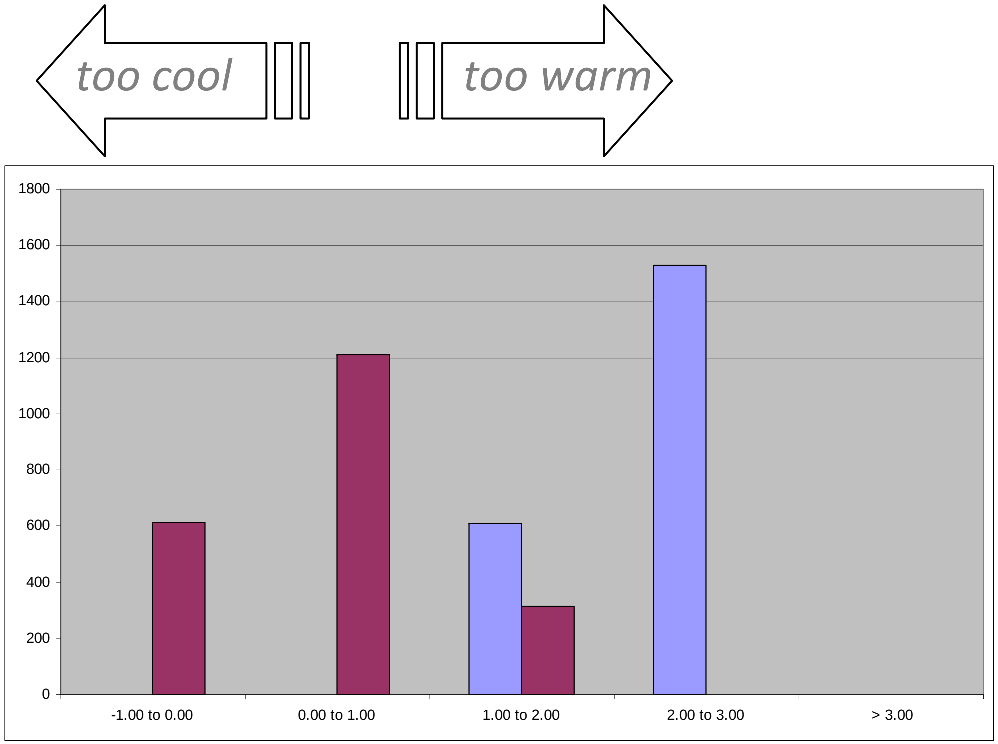
(*Milton Wheelhouse, Stirling*)



hours cooling required over 26deg C

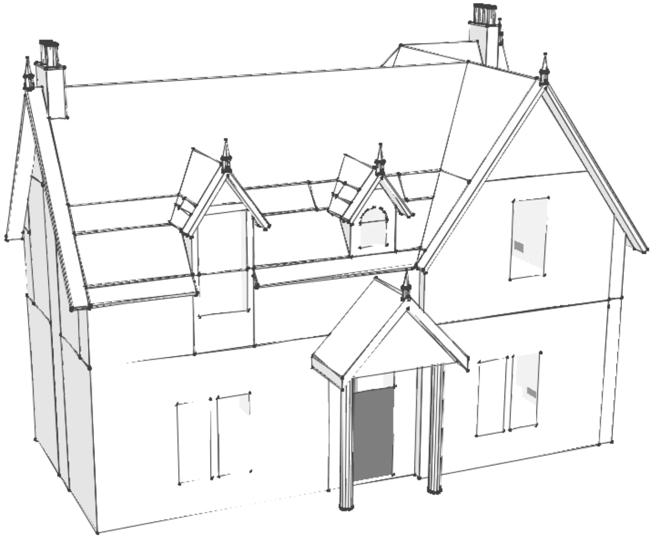
exposed mass

mass covered



need for additional retrofitted cooling?

Milton Wheelhouse, Stirling



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