Innovative Use of Aerogel in Passive and Active Solar Storage Walls Mark Dowson - CIBSE Building Simulation Group – 2nd June 2011 But Happoid

Mark Dowson – CIBSE Building Simulation Group – 2nd June 2011

Presentation outline:

- My background
- Research focus
- Two modelling case studies
 - Passive solar storage wall (i.e. a Trombe wall)
 - Active solar-air collector
- Questions

Mark Dowson – CIBSE Building Simulation Group – 2nd June 2011

My background:

- Research engineer based in industry
- Currently undertaking an Engineering Doctorate (EngD) in Environmental Technology
- Industrial project sponsored by Brunel University and Buro Happold Ltd

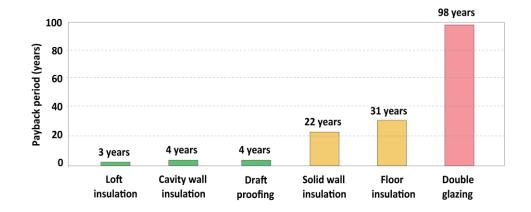
Buro Happold:

- Global engineering consultancy for the built environment
- Sustainability and Building Physics team (London)

Focus of my research:

Developing and testing new building fabric technologies incorporating high performance
 silica aerogel insulation to reduce demand for heating and artificial lighting in buildings



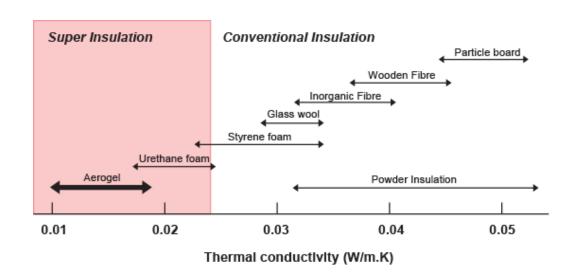


- Millions of homes in the UK are poorly insulated and expensive to heat
- Some conventional solutions to improve these homes are not cost effective



What is aerogel?

- Transparent "super-insulation" material
- Invented in the 1930s; only now emerging in the construction market
- Translucent granules are mass produced
- Solid tiles can be produced, but they are fragile and expensive, thus are not commercially available



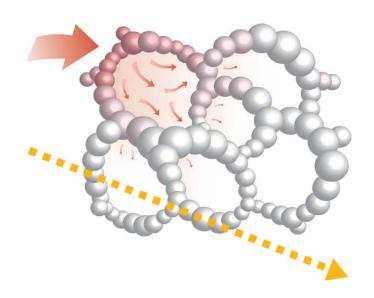


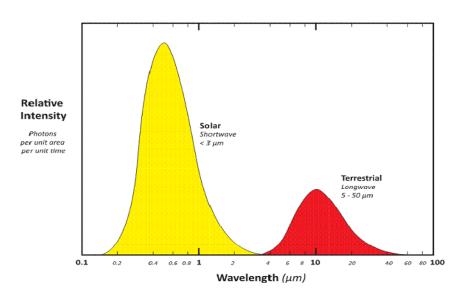




How does it work?

- Material contains a nanoporous structure up to 99% air (1% silica)
- Nanosized pores block heat transfer by *convection*, *conduction* and *long-wave thermal radiation*
- Silica structure is highly transparent to *light* and *short-wave solar radiation*





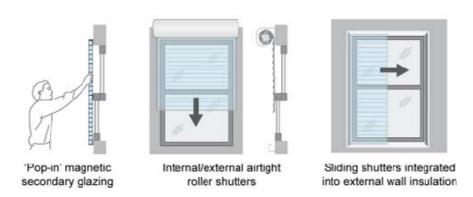


How can it be used?

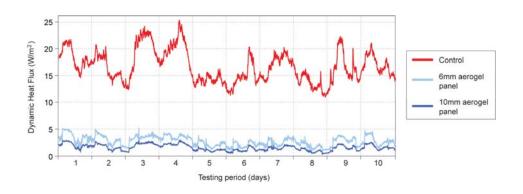




Concepts to insulate existing windows:



Measurements show an 80% reduction in heat loss!





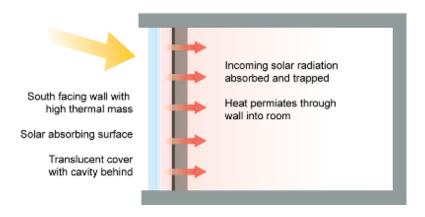


Concepts for passive solar storage:

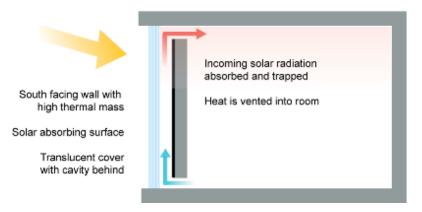
- High performance cover in south facing solar storage walls
- Aerogel has a lower solar transmission to standard single glazing but significantly reduces heat losses

Let solar energy in. Trap it. Let it accumulate. Use it

Unventilated trombe wall:



Ventilated trombe wall:



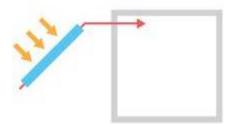


Concepts for active solar collection:

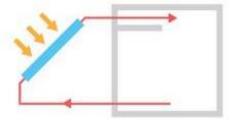
- Supply free solar heated warm air to a space instantaneously
- Storage can be introduced through PCM in collector or ductwork
- Air-water heat exchangers can avoid wasting heat in summer

Let solar energy in. Trap it. Let it accumulate. Use it

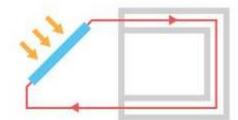
Solar heating of outside air supplied directly to space



Solar heating of room air returned via thermal storage in roof



Solar heated air circulated through cavity in the building envelope





CASE STUDY 1: Aerogel Trombe wall

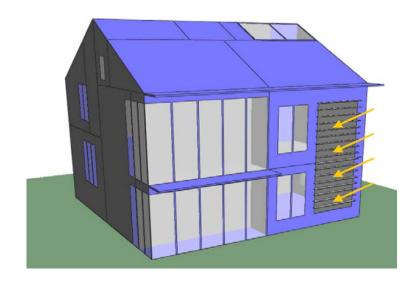
Riches Hawley Mikhail Architects

Robinson Associates Engineers

- Concept currently planned for a new eco-home in the UK
- Property will be highly insulated and have high thermal mass
- Aerogel Trombe wall is anticipated to reduce need for heating during cold-mild sunny days

Approach used:

- Parametric calculator built in Excel
- Model combines building parameters obtained through IES Virtual Environment software with average solar radiation and degree-day data for the site.
- Max allowable area = **7.5m**²





Calculation methodology:

Duffie and Beckman (2006), Solar Engineering of Thermal Processes

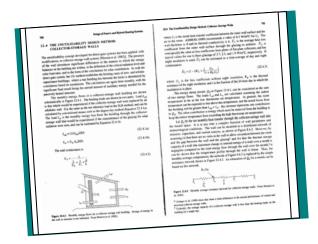
Third Edition, John Wiley & Sons Inc, New York, USA

- Widely cited book to predict the performance of solar technologies
- Calculations validated through TRYNSYS simulations + measurements
- Educational software available from www.fchart.com

SOLAR ENGINEERING OF THERMAL PROCESSES JOHN A DUFFE WILLIAM A BECKMAN

Contents include:

- Solar radiation calculations
- Transmission properties of materials
- Passive, active and hybrid solar technologies
- Energy storage systems
- Financial modelling



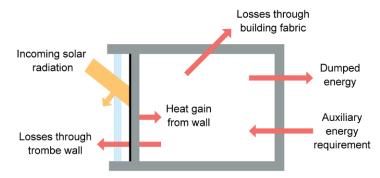


Overview of method:

Chapter 22: Un-utilizability design method for collector-storage walls

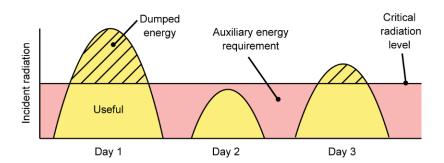
- Method assumes system is unvented and heat transfer though the wall is linear
- Calculates a buildings monthly-average heat load with + without a Trombe wall, based upon:
 - Absolute upper and lower limits of the building and walls thermal capacity
 - Storage-dump ratio, defined by the systems actual thermal capacity

Trombe wall energy balance:



Storage-dump concept

(for zero capacitance system):



1.03 1.03 12.4 71.3 201.4 1.01 271.3 4.01 4.01 1.11 1.11



Characterise site

- latitude
- longitude
- ground reflectance

Characterise building \

- Heat loss parameter
- Thermal capacity
- Stat set points
- Allowable temp swing

Characterise wall

- Area
- Thickness
- Heat capacity
- Density
- Conductivity
- Loss co-efficient

Characterise cover transmission

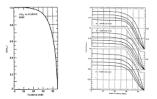
- Solar transmission
- Solar absorptance
- Solar reflectance
- Overall product in terms of beam, diffuse and ground reflected radiation



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Monthly-average values Characterise months

- Degree days
- Ambient temp
- Days in month
- Average total solar radiation

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Parametric calculator

Characterise months

Hambers of days is a mostle

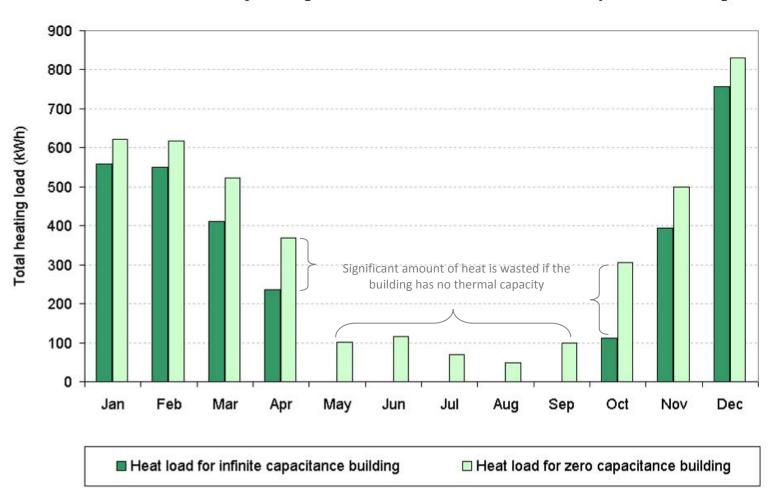
Performance Calculations

- Daylight hours
- Solar radiation absorption calcs
- Building loads
- Wall temperature
- Critical radiation & energy dump calcs
- Storage capacity of wall & building
- Solar fraction & Net energy gain

Summary table of key results

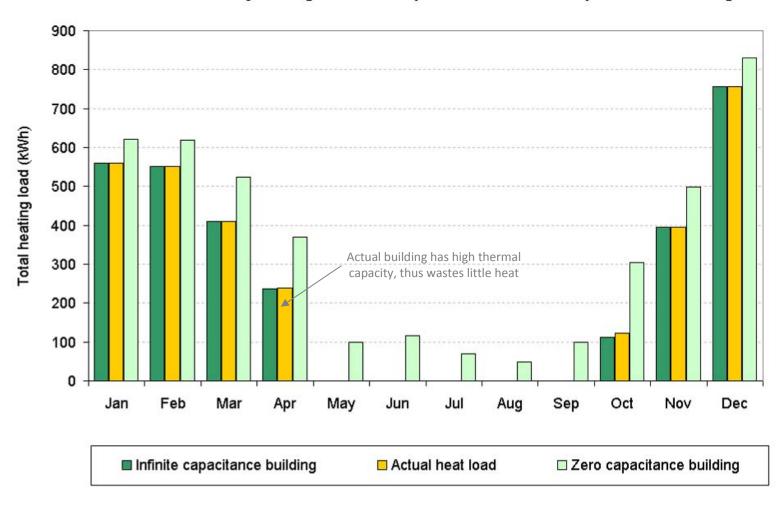


Predicted Monthly Heating Load in "Infinite" and "Zero" thermal capacitance building



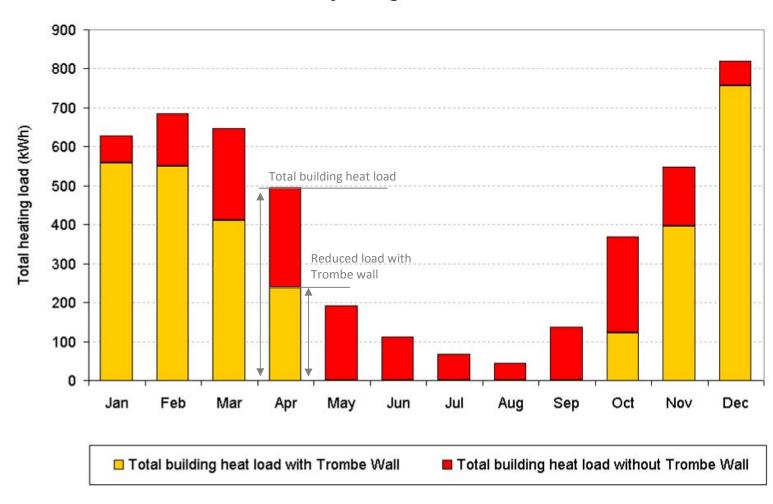


Predicted Monthly Heating Load based upon "Actual" thermal capacitance of building



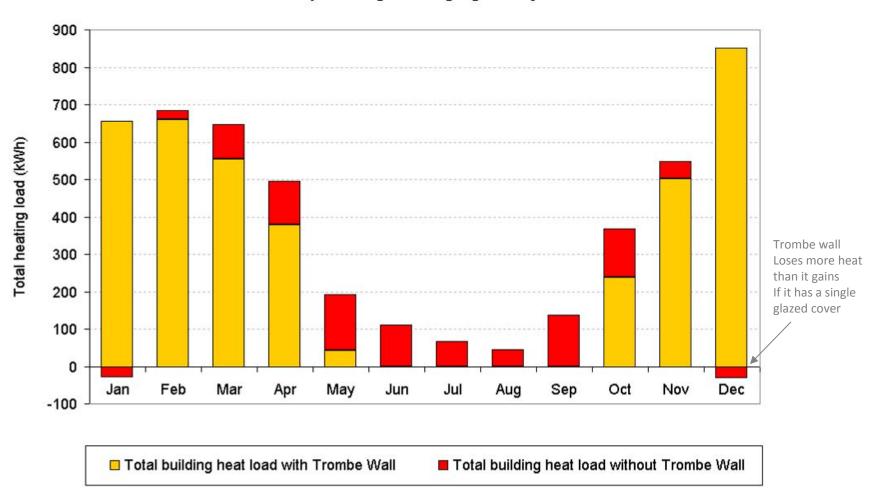


Predicted Monthly Heating Load with/without the Trombe Wall



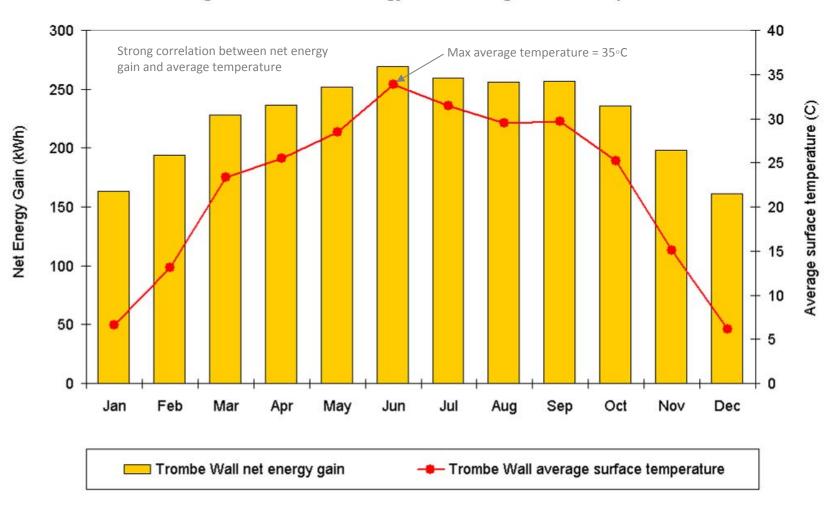
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Comparison against single glazed system



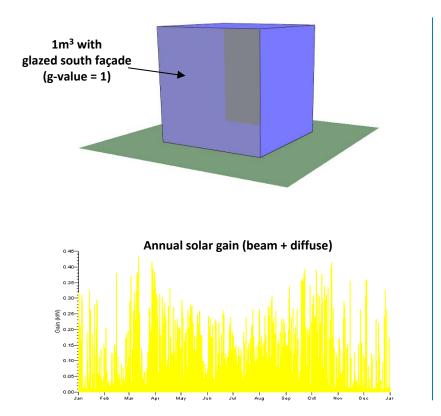


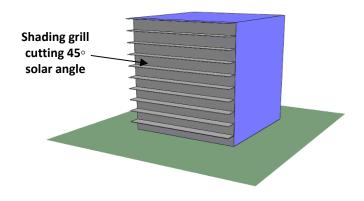
Aerogel Trombe Wall Net Energy Gain & Average Surface Temperature

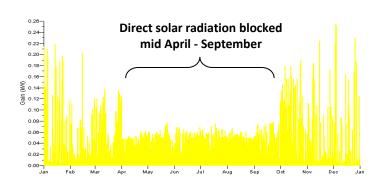


Summertime overheating mitigation

• Calculator assumes wall is un-shaded, but basic modelling can demonstrate benefit of shading grill:





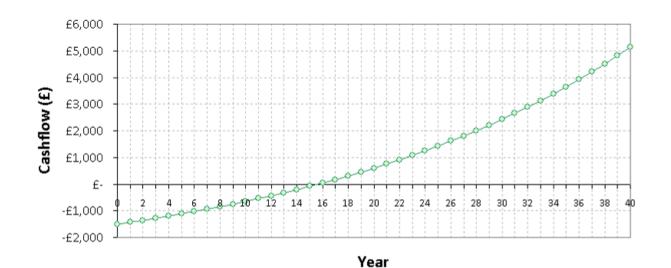




Key results:

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual total
Energy requirement (no trombe wall)	kWh	627	685	648	495	192	111	67	44	137	368	548	819	4741 kWh/year
Energy requirement (with trombe wall)	kWh	559	551	411	238	0	0	0	0	0	122	395	756	3033 kWh/year
Solar fraction	-	0.14	0.22	0.39	0.54	1.00	1.00	1.00	1.00	1.00	0.68	0.30	0.11	61 %
Energy savings (84% efficient bolier)	kWh	81	159	282	306	229	132	80	52	163	293	182	75	2034 kWh/year
Fuel bill savings (0.04p/kWh gas)	£	3.2	6.4	11.3	12.2	9.1	5.3	3.2	2.1	6.5	11.7	7.3	3.0	81 £/year

Preliminary payback graph:



<u>Assumptions</u>

Capital cost £ 1,500
Fuel price increase rate 6% per year
Interest rate 2% per year

Net present value

Year 5 -£	1,110
Year 10 -£	650
Year 15 -£	80
Year 20 £	598
Year 25 £	1,42
Year 30 £	2,433
Year 35 £	3,65
Year 40 £	5,12



CASE STUDY 2: Aerogel Solar Collector

- Concept currently being constructed as part of the 'Retrofit for the Future' competition
- Property is a 3 storey 1960's end-terrace in Thamesmead, South East London
- Refurbishment strategy must achieve deep CO₂ reductions in order of 80%





Refurbishment strategy

- Aspiring towards Passivhaus certification
- Externally insulating building
- Triple glazing throughout
- Air-tight tapes on all junctions
- Mechanical ventilation with heat recovery
- DHW from boiler + solar thermal panels
- Electricity from roof mounted PVs









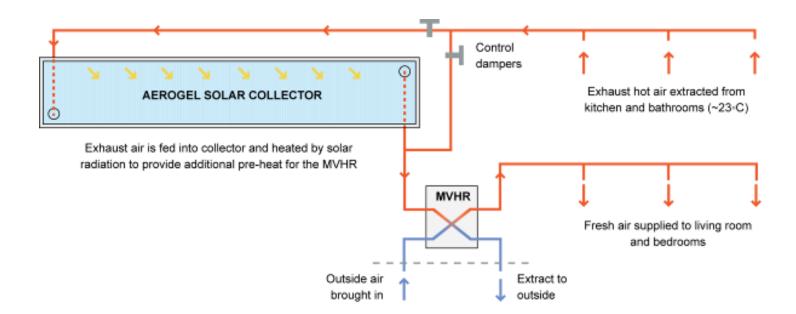
MARTIN ASSOCIATES CHARTERED SURVEYORS



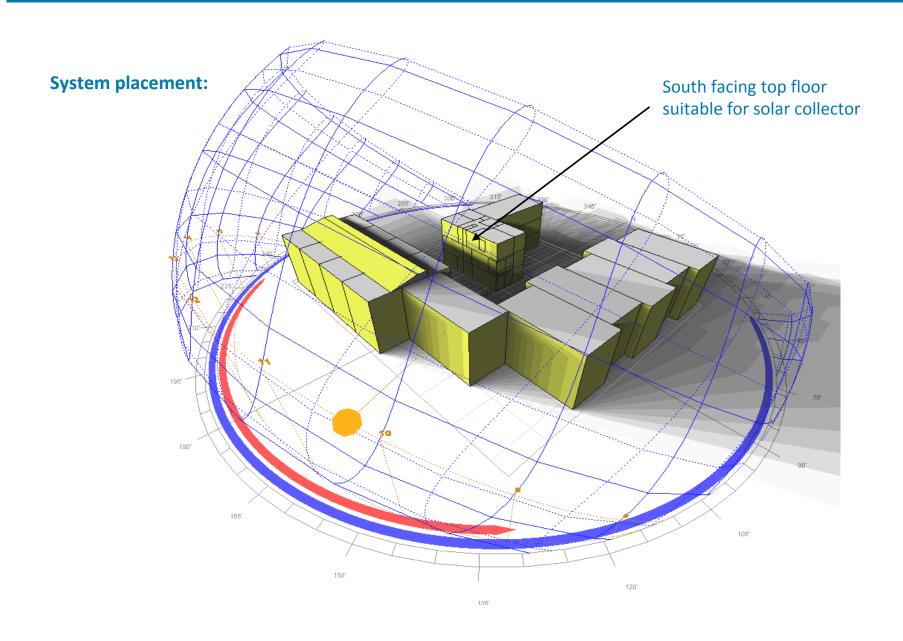


Aerogel solar collector

- Active solar-air system anticipated to increase the efficiency of the MVHR
- Normally an MVHR uses extracted heat from the kitchen/bathrooms to indirectly pre-heat incoming air
- Aerogel solar collector will be used to elevate this extracted air to higher temperatures



Mark Dowson – CIBSE Building Simulation Group – 2nd June 2011







Modelling Validation:

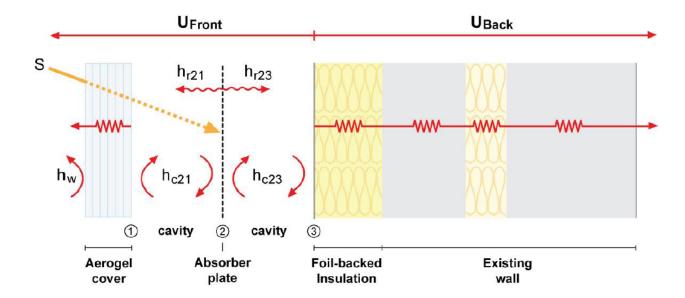




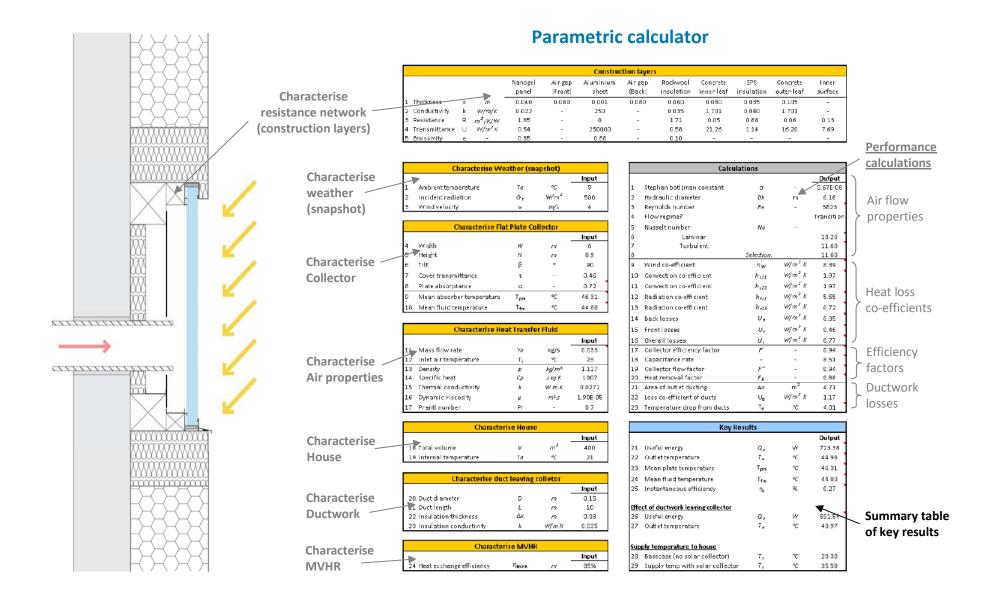
Calculation methodology:

Duffie and Beckman (2006) - Chapter 6: Flat plate solar air heater

- Parametric Excel tool combining design constants from steady state modelling with dynamic annual-hourly climate data generated using IES Virtual Environment software
- Model calculates outlet temperatures and energy generation before/after the ductwork leading to MVHR



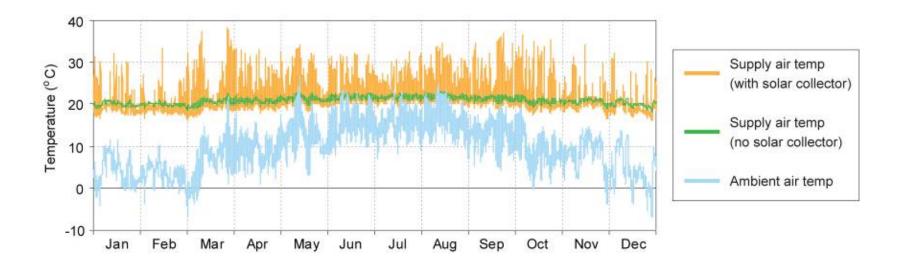






Predicted supply air temperatures:

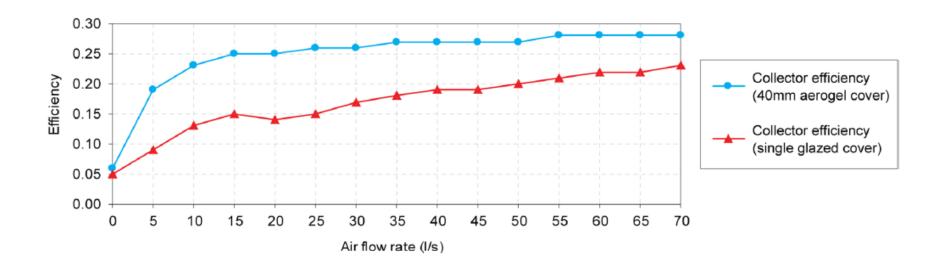
- Predicted supply-air temperatures up to 30°C on cold-mild sunny days
- Peak temperatures up to 40°C in March & September indicating bypass controls required



- Note that supply air temperatures without solar collector are predicted between 18-21 °C
- However, this may not be accurate as model assumes constant flow rate & exhaust air temp of 23°C



Efficiency compared to single glazed system:



Notes on efficiency:

- System located on vertical wall not at 30° pitch
- System inlet temperature higher efficiency occurs if system heats ambient air directly
- Absorber sheet is perforated efficiency calculation assumes absorption area is reduced



Next steps:

- Construction
- Monitoring
- Validation





Installation of solar collector frame:









Installation of pre-fabricated ductwork:







Innovative Use of Aerogel in Passive and Active Solar Storage Walls





Aerogel panels, absorber sheet MVHR + flow control dampers:



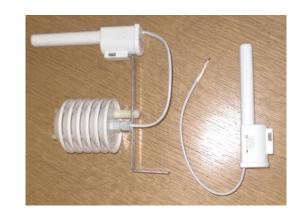






Monitoring & Validation:

- Whole house
 - Gas, electricity + water consumption
 - Internal + external temperatures and humidity
 - Performance of renewable technologies



Aerogel solar collector:

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T ₁	T ₂	Тз	Toutlet
Tinlet	T ₄	T 5	T 6

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Thank you for listening

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Modelling Reference:

Duffie and Beckman (2006), Solar Engineering of Thermal Processes Third Edition, John Wiley & Sons Inc, New York, USA