DESIGN AND PERFORMANCE OF AN EXTERNAL BUILDING ENVELOPE RETROFIT SOLUTION FOR A GRID OPTIMISED CONCRETE STRUCTURE: A CASE STUDY

P. O’Sullivan, F. Delaney, M. O’Riain, T. Clancy, J. O’Connell, D. Fallon

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HENRY J LYONS ARCHITECTS

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Introduction

- Recently completed pilot project at Cork Institute of Technology
- covered 1.5% of the total existing building footprint & aims to create a template for a phased full building retrofit
- Retrofit in live buildings will have to be phased and as non-invasive as possible
- phased, modular, scalable, flexible, durable external retrofit with an intermediate internal retrofit is the most suitable design solution (coupled with a largely off-site build)
- primary aim of the envelope upgrade is to extend the lifetime of the building and ensure low thermal energy demand and improved occupant comfort

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Context

- Buildings in Europe account for **40% of energy consumption**
- Article 9 of Directive 2010/31/EU "Energy Performance of Buildings (Recast)" brings in refurbished buildings under the near zero-energy umbrella by requiring member states to develop policies in order to stimulate the transformation of refurbished buildings into near zero-energy buildings (NZEB)
- Article 7 of Directive 2010/31/EU states that *when buildings undergo major renovation, the energy performance of the building is upgraded in order to meet minimum performance requirements set in accordance with Article 4*.

Basis of design

- Environmental criteria:
  - winter indoor operative temperature — 21-23^{o}C
  - summer indoor operative temperature — 25^{o}C
  - overheating criterion: Tint — 28^{o}C < 1% of AOH
  - The required ventilation rate — 10 $ls^{-1}person^{-1}$,
  - maintained luminance of — 300-500 lux
  - noise level rating — NR30
- design strategy :
  - ensure compliance with the environmental specification for occupant comfort
  - achieve the best fabric and energy performance subject to constraints imposed by budgets and retrofit/structural limitations.
- Resulted in U-values for opaque element 3 times better than current regulations and glazing U-values 6 times better

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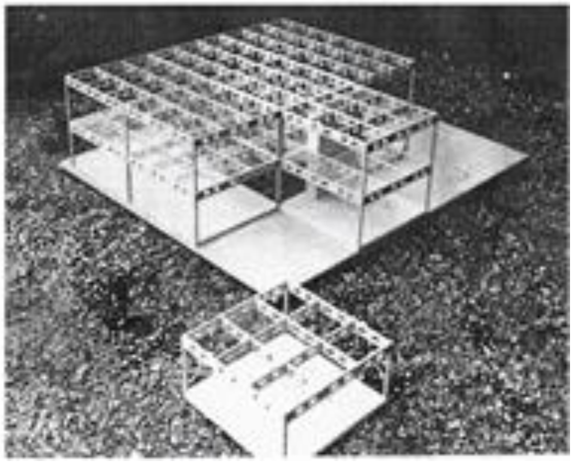
Original grid optimised structure

- Designed in 1967
- modular two storey reinforced concrete precast structural frame
- externally hung concrete aggregate panels
- single glazed aluminium windows
- Initially building lifespan was intended to be 20 years
- existing internal subdivision and existing structural grid pointed the design toward a grid optimized solution, reducing internal change





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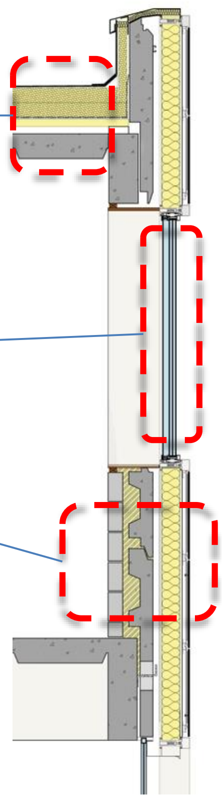
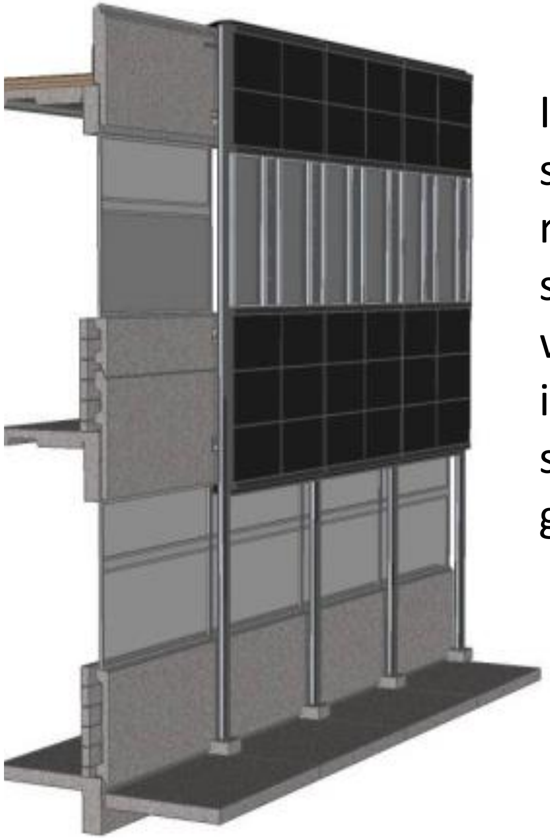
Component Orientated Solution

Roof Component

Fenestration Component

Opaque Wall Component



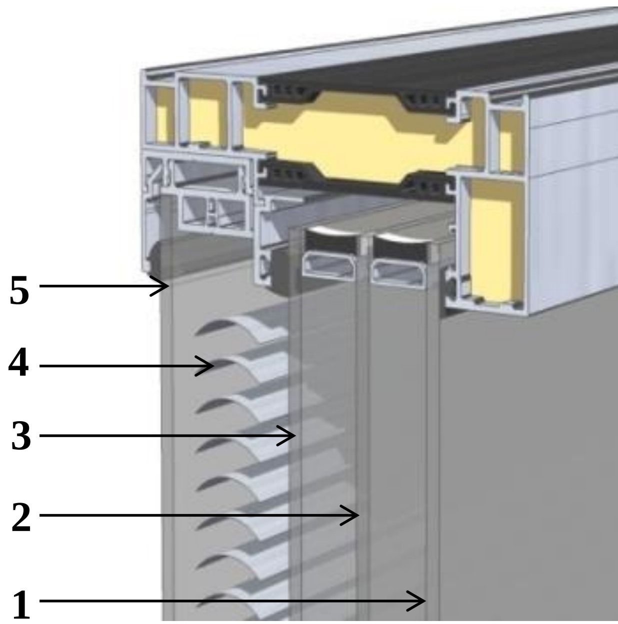


Integrated modular systemised external retrofit – existing structure retained with new envelope independently supported at ground level

Fenestration component - glazing

Layer	Description	Dim
1	SG* Low-e Planitherm Total +	4 mm
	90% Argon filled gap	16mm
2	SG* Low-e Planitherm Total +	4 mm
	90% Argon filled gap	16mm
3	SG*Planilux clear float	4mm
4	16mm interstitial slat blind	24mm
5	4mm Clear Float	4 mm

- Each glazing unit is 1800mm x 800mm
- 2 glazing units for every module
- Alternative fenestration specifications depending on façade orientation (South & North)
- The total SHGC for South is 0.296 and the VT is 0.150
- The U-value of these glazing/interstitial blind components is 1.0 W/m^{2}k (COG value of 0.82 W/m^{2}k)



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Fenestration component - ventilation

- Building can be classified as having a free-running indoor temperature as no HVAC system is used
- In existing building the ventilation system is based on single sided top hung pivoting windows located at 1.5m above finished floor level
- Retrofit ventilation module uses a flush faced louvre with individual air inlet sections and at same height AFFL.
- The retrofit envelope air permeability was tested in accordance with BS EN 13829:2001 .
- The envelope achieved an air permeability of 1.76 $(m^3/hr)/m^2$ at 50Pa building pressure. The existing structure was measured as 14.77 $(m^3/hr)/m^2$

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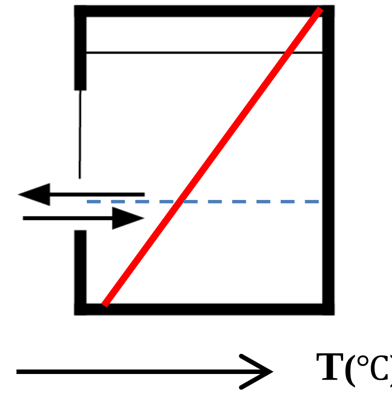
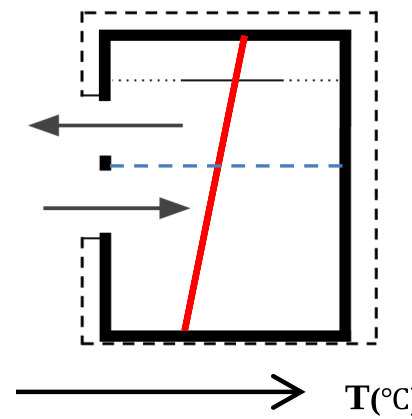
Fenestration component – ventilation

Summary Characteristics	**Opening**	**Indicative* temp gradient & flow pattern**
Existing Envelope $A/A_w = 3.7$ $A_{total\ ,module} = 0.32m^2$ C_p, C_1 & C_2 required to model Occupant controlled Limits NPL* height Security issue for nocturnal cooling Poor airtightness		
Retrofit Envelope $A/A_w = 4.9$ $A_{opening} = 0.008m^2$ $A_{total\ ,module} = 0.42m^2$ C_p & C_d required to model Increases NPL* height Automated & Occ controlled Nocturnal cooling potential Excellent airtightness	 	

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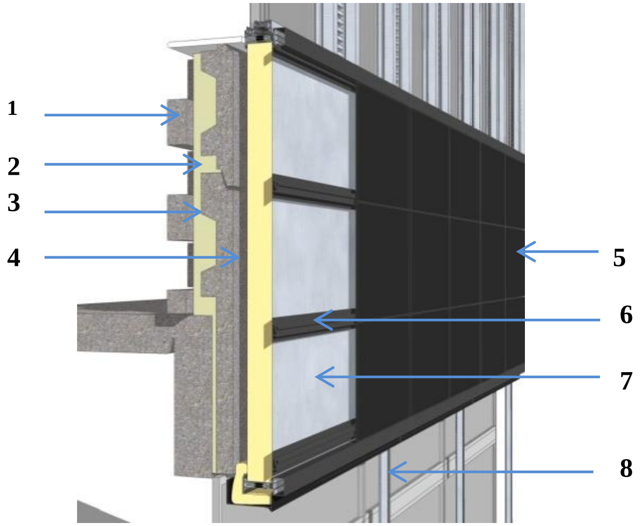
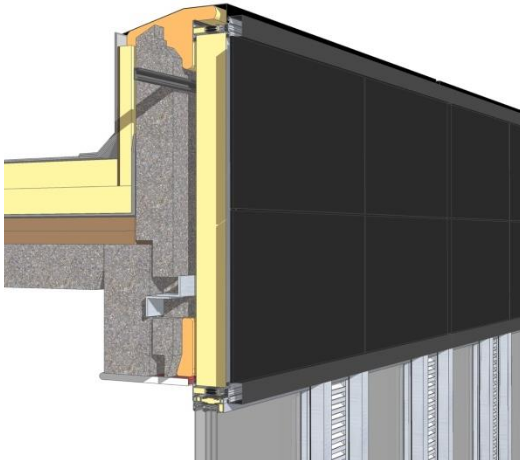
Opaque Wall & Roof components

Layer	Description	Dim (mm)
1	Existing internal block	100
2	BASF Walltite spray foam	86
3	Existing aggregate panel	125
4	Air gap	30
5	Kingspan Benchmark ceramic granite panel	12
6	Kingspan support rail	37
7	Kingspan KS1100 insulated panel	125
8	AMS support mullion	125

External wall below window level	Roof Pre retrofit	Roof Post retrofit	Wall Pre retrofit	Wall Post retrofit
Internal thermal admittance, $W/(m^2.K)$	7.21	7.22	5.49	5.92
Time shift for internal thermal admittance, h	1.452	1.424	1.017	0.963
Periodic thermal transmittance, $W/(m^2.K)$	0.4632	0.0080	2.2089	0.000 4
Time shift for periodic thermal transmittance, h	-6.137	-15.32	-4.846	-15.83
Thermal transmittance, $W/(m^2.K)$	1.156	0.092	3.633	0.090
Decrement factor	0.401	0.087	0.608	0.004





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Modular, grid based installation

- All mullion and transom sections are extruded from aluminium alloy 6063 T6
- Direct connection to the existing aggregate panels was not structurally feasible
- bracket detail designed that would connect to the main structure behind the panels
- extended out beyond the structure and the line of existing aggregate panel so that the vertical bespoke mullions could be attached
- function of these fixings was to counteract all wind loadings imposed on the façade
- All the dead loads were transferred to a pad foundation which was poured directly below each main mullion

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Manufacturing & Installation Process

The design brief stipulated that the envelope solution :

- should be an indigenous product
- scalable in nature
- off-site build

The solution was the The AMS 7-5 high performance "renovate" system & TS125 low energy window system design and manufactured in Little Island, Cork

New high performance curtain wall solution was easily constructed and assembled so as to minimise disruption on site, and also allowed ease of integration with the Kingspan Benchmark system (opaque PIR Insulation components).

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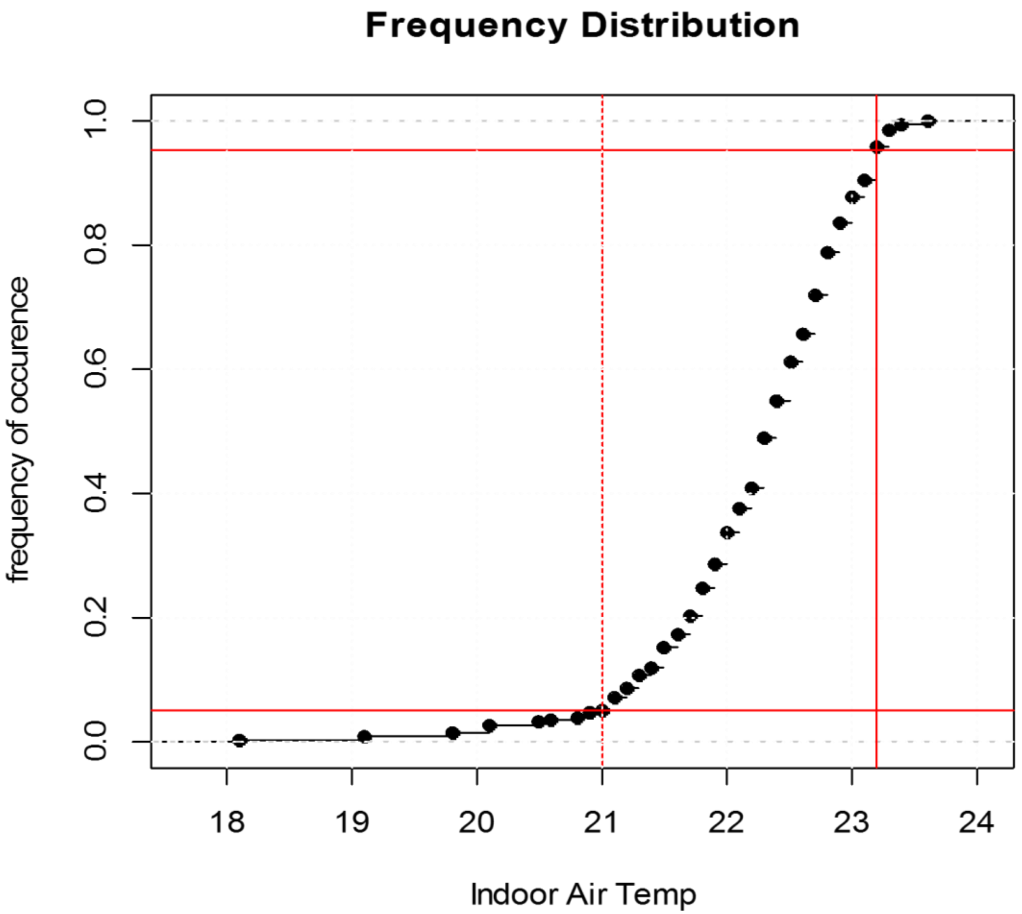
Current Internal Environment

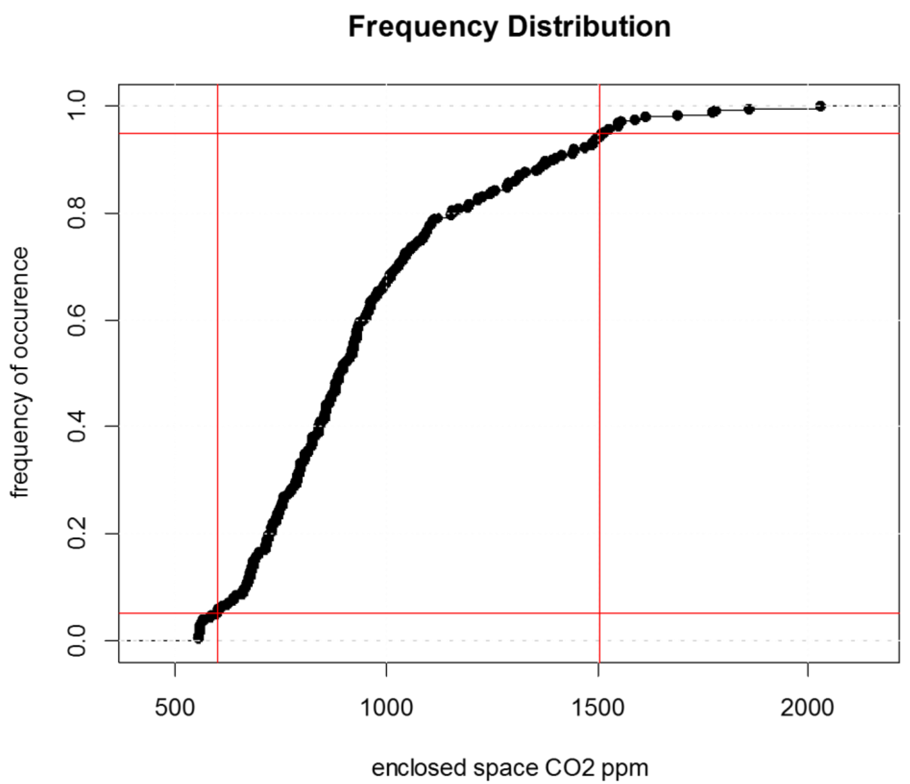
- Results are presented for a 5 week period spanning 18th February to 24th March 2013 inclusive
- The occupancy schedule is from 8.00 to 18:00 hours, Monday to Friday inclusive
- The heat pump runs from 8:00 to 15.30 hours
- 81% of the time the internal air temperature lies within the 21-23°C comfort range (note that for well insulated, air tight buildings operative temperature is approximately the same as air temperature)
- 13% of the time the temperature is in the 23 to 23.5°C range, marginally outside the comfort criteria



5 week, occupancy hours Cumulative Frequency Distributions for indoor air temperature (red lines show 95 percentile and 5 percentile values)

Current Internal Environment

- High air quality, as defined in EN 13779:2007, is achieved 33% of the time and medium air quality 34% of the time
- Range of conditions based on 5% confidence intervals is 600 – 1500 ppm. 50th percentile value 850ppm



5 week, occupancy hours Cumulative Frequency Distributions for indoor CO_2 ppm (red lines show 95 percentile and 5 percentile values)

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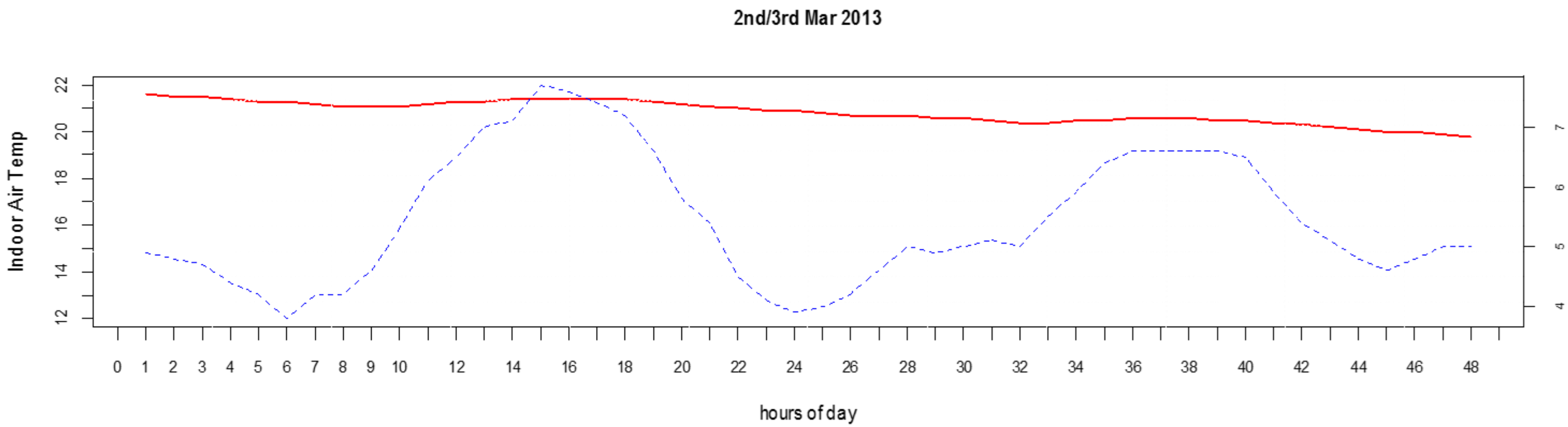
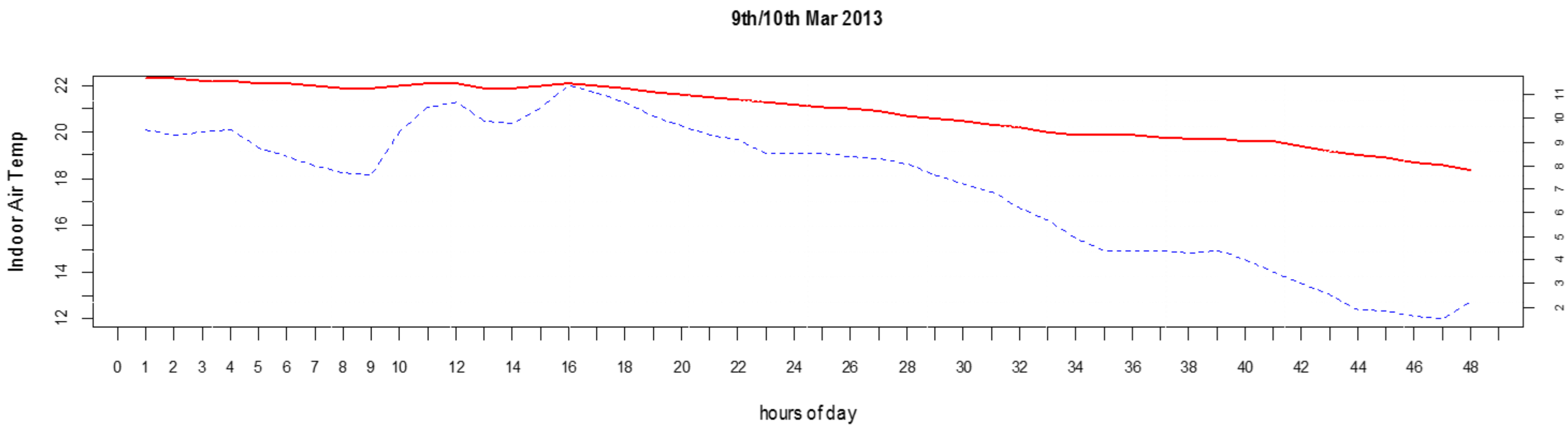
Intermittent Operation





Indoor air temp versus external air temp over 2 weekends with no heating scheduled on (2/3 Mar & 9/10 Mar) (red line indicates internal air temp; blue line external air temp)

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Conclusion

- The envelope retrofit has proven to be both modular and scalable as a retrofit system
- The solution demonstrated a high potential for very good thermal comfort levels
- However, the indoor air quality is highly dependent on user control of the ventilation louvres
- Temperatures above 23^{o}C and CO_2 levels above 800-1000ppm could both be reduced if the louvres were used more effectively
- The footprint covered by the envelope solution has demonstrated very low levels of thermal energy demand to date. (The dedicated Air Source Heat Pump system has consumed 568.9 kWh since February 21st 2013)

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