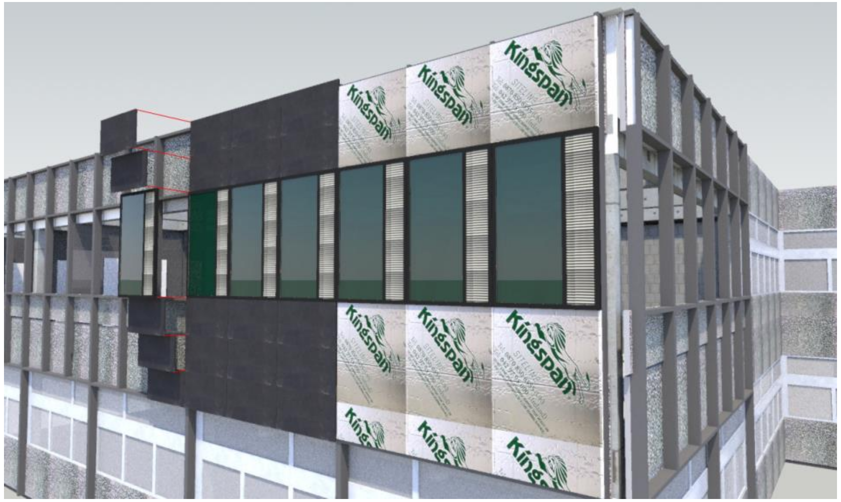
PASSIVE RETROFIT DEMONSTRATION 1974 (PRD74)



Low Energy Retrofit testbed @ Cork Institute of Technology

Paul O Sullivan & Marc O Riain (CIT PRD)

Towards a low energy Retrofit

11/11 *for* **20/20**

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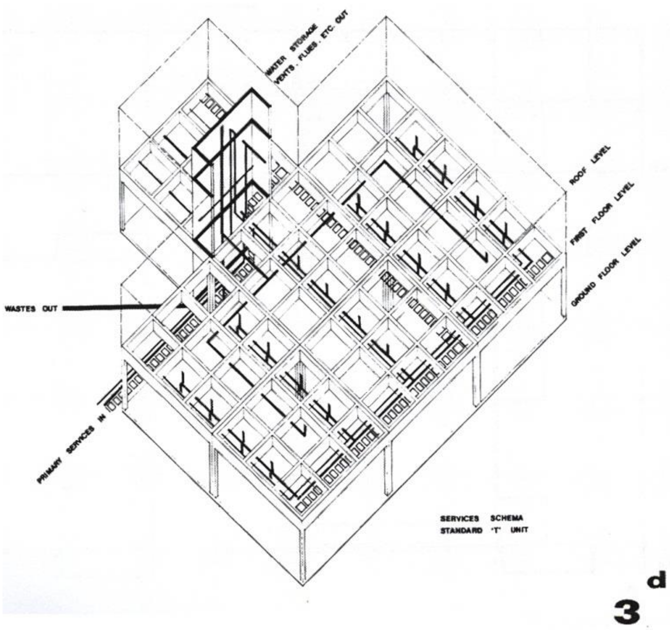
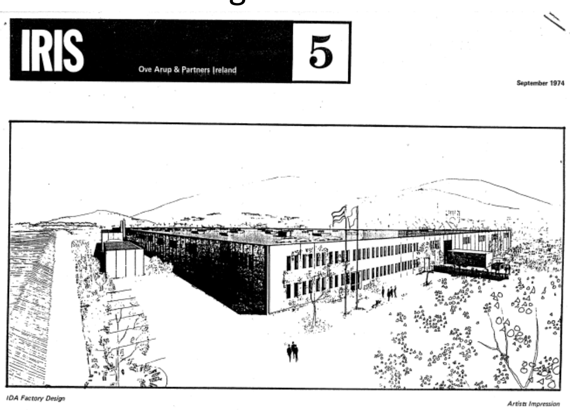
The Regional Technical College buildings were constructed in 11 locations around Ireland from 1970 to 1977. They were all constructed from a basic common design and varied in size and specification responding to the constraints of individual sites. There were intended to have a lifespan of 20 years.

Today all exist and continue to serve a purpose in third level education. At CIT the nature of their construction does not conform to contemporary building standards, are poorly insulated and are very costly to maintain.

As a result many of the Institutes of Technology who own these buildings are looking at redeveloping them in line with current building standards.





History

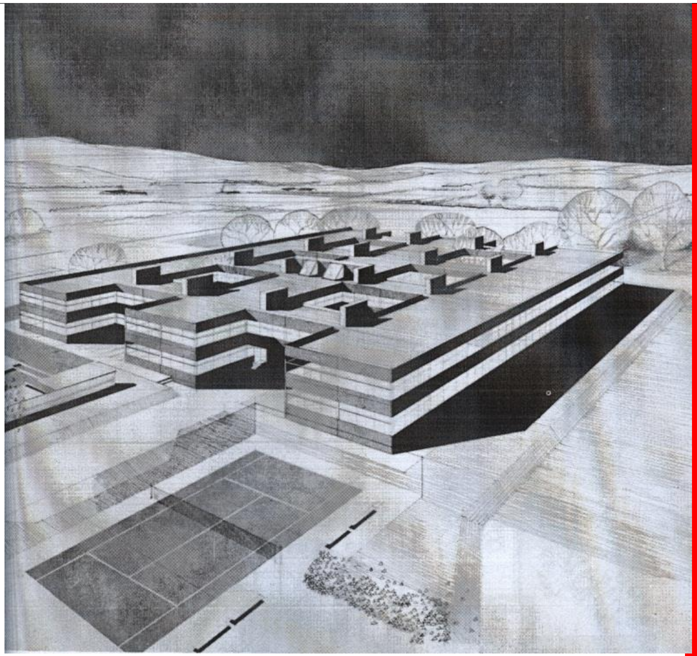
In February 1967, the new Minister of Education appointed a design team for the new Cork Regional Technical College. The formation of the design teams had taken place and O'Malley had set up Building Design Associates as the design team for regional technical colleges at Dundalk, Galway, Sligo and Waterford.

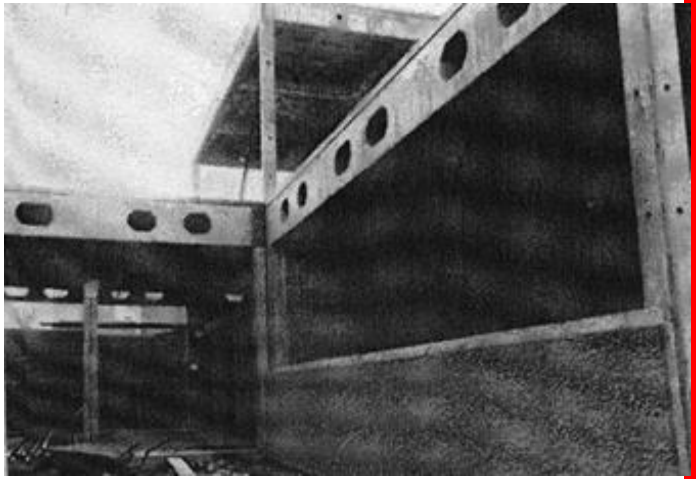
The design was originated by a consortium formed as a design team which were hand picked by the Fianna Fail Minister of Education, Donogh O Malley in 1966/67 (Magill 04/88).

The Architect Micheal Scott appointed John Burgess from his design team to work with Jock Harbinson from ARUP, Arthur Gibney , Richard Mayne, Eoin Kenny and Desmond McGreevey a prominent Dublin Quantity Surveyor .

Here in Cork the design team differed with O Flynn Green Architects, Varmings, ARUP and James Sheehan.

The estimated cost in 1969 of the 9 Colleges is £7,129,0001





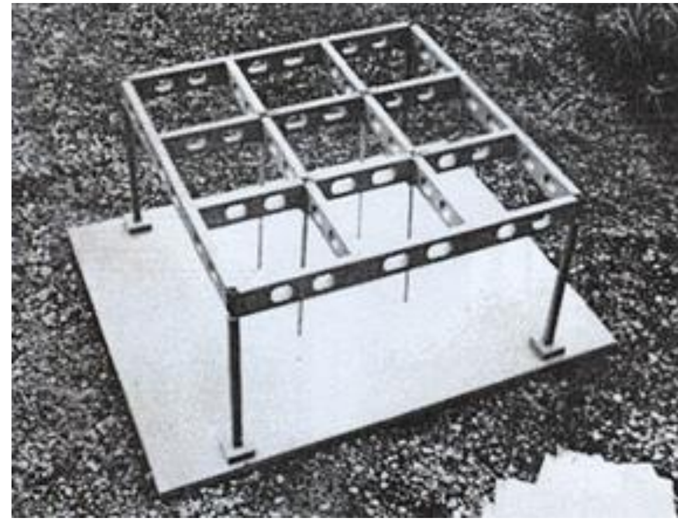
The design has to be pulled together very fast so the design team visit Birmingham where ARUP have just completed the M&M Building.

They replicate the structural design almost regimentally.

The M&M Building uses an innovative twin skin full height glazed envelope with natural ventilation between structures. Internally, the quality of the finishes exceeds that of its Irish counterparts.

Quality fair faced Brick, timber panelling, fanlights, natural light, and hardwood floors all contribute to a qualitative interior space.

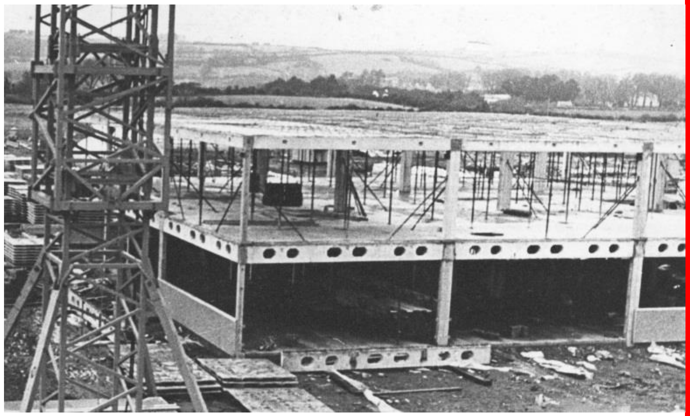
The M&M is listed externally



The original structure comprises a two storey precast un-insulated concrete building, with an un-insulated 100mm castellated concrete roof panels and original 6mm clear single glazing with aluminium frames. The extent of the retrofit scope under this phase is limited to the first floor with south, west and north elevations.

The existing building is pre building regulations and has a very poor performing thermal envelope with a very high level of air infiltration and subsequent uncontrolled heat loss.

Furthermore, the existing fabric has deteriorated since its 1974 completion date and in particular its 30% glazing coverage has a thermal transmittance U-Value of greater than 5.5 W/m^{2}K including frame (300% worse than current building regulations recommended levels of performance).



The Department of Education (DoES) has been involved in various fabric retrofits in Letterkenny, Dundalk, Sligo and Carlow, which have had various architectural targets.

In Carlow it was limited to an aesthetic fabric improvement that delivered a new vertical envelope but did not contribute to energy savings.

In 2002 Letterkenny was renovated by Coady Architects to deliver a renovation in compliance with the existing Part L of the building regulations. There has been no assessment of the post occupancy performance.

Recently a VEC in Dundalk , with the same building language, was also renovated by Coady Architects with a greater focus on air tightness and low operational energy.

However, building energy researches at CIT wanted to establish whether a retrofit of the 1974 building could achieve the 20/20 aspirations of the Building Energy Performance Directive (recast 2010).

In CIT we are starting this at home!

We are creating the first low energy Commercial retrofit test bed project in Ireland!

Towards a low energy Retrofit

11/11 *for* **20/20**

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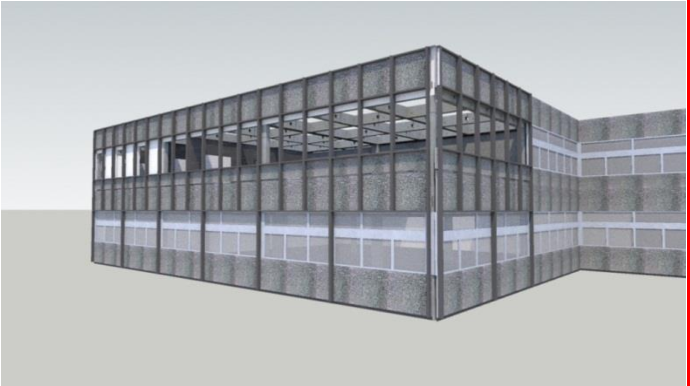
- The college only wanted to meet current building regulations
- We wanted to see if we could meet the Energy Performance in Buildings Directive for 20/20.
- **A LOW ENERGY SPACE!**
- To demonstrate low energy passive retrofit strategies for existing buildings supplemented by renewable, active energy supply technologies.
- Provide full monitoring and metering of all energy flows into and out of the space to allow full diagnostic capability on both energy demand sources and energy supply systems performance.

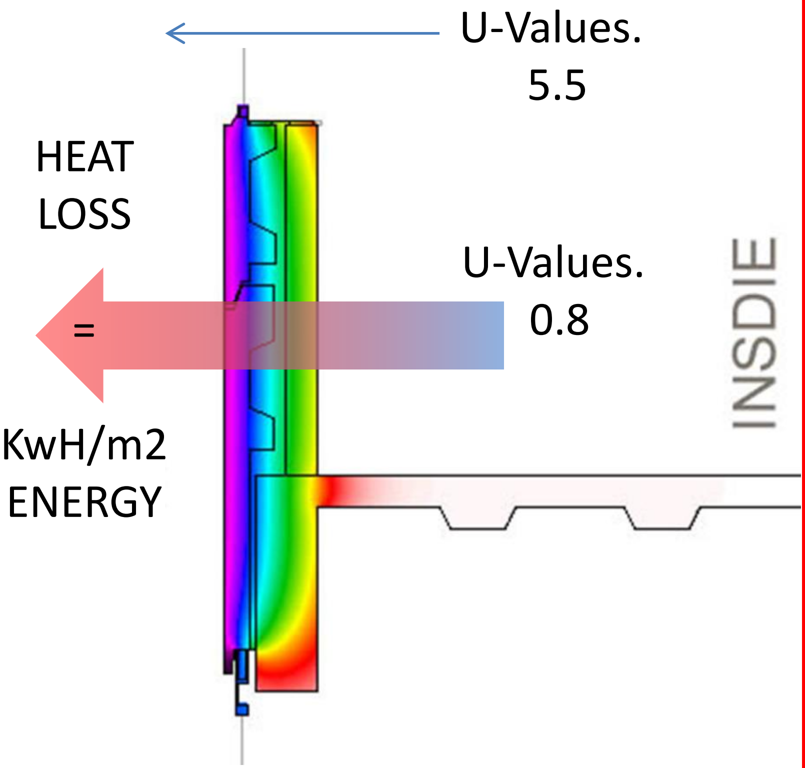
Source: ASHRAE, Internal JCI analysis

Fabric And Envelope

<u>The original structure comprises of:</u>

- Two floor precast un-insulated concrete building
- Single glazed aluminium windows.
- The extent of the redevelopment is limited to the first floor with south, west and north elevations
- Poor thermal performance
- Very high level of air infiltration
- fabric deterioration
- 30% glazing coverage





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Design Methodologies:

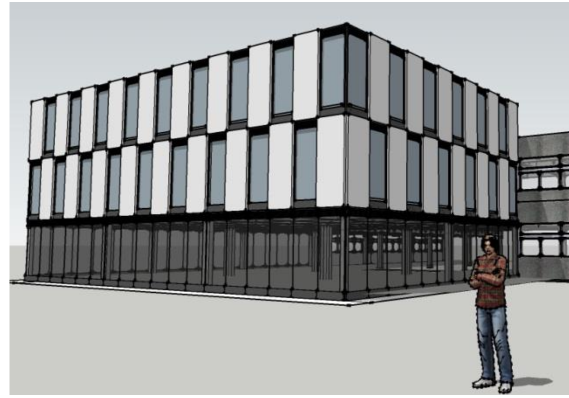
Early design concepts considered a third floor and reducing the glazing proportion.

The verticality of the volume was considered and was not out of character with the architects original influences.

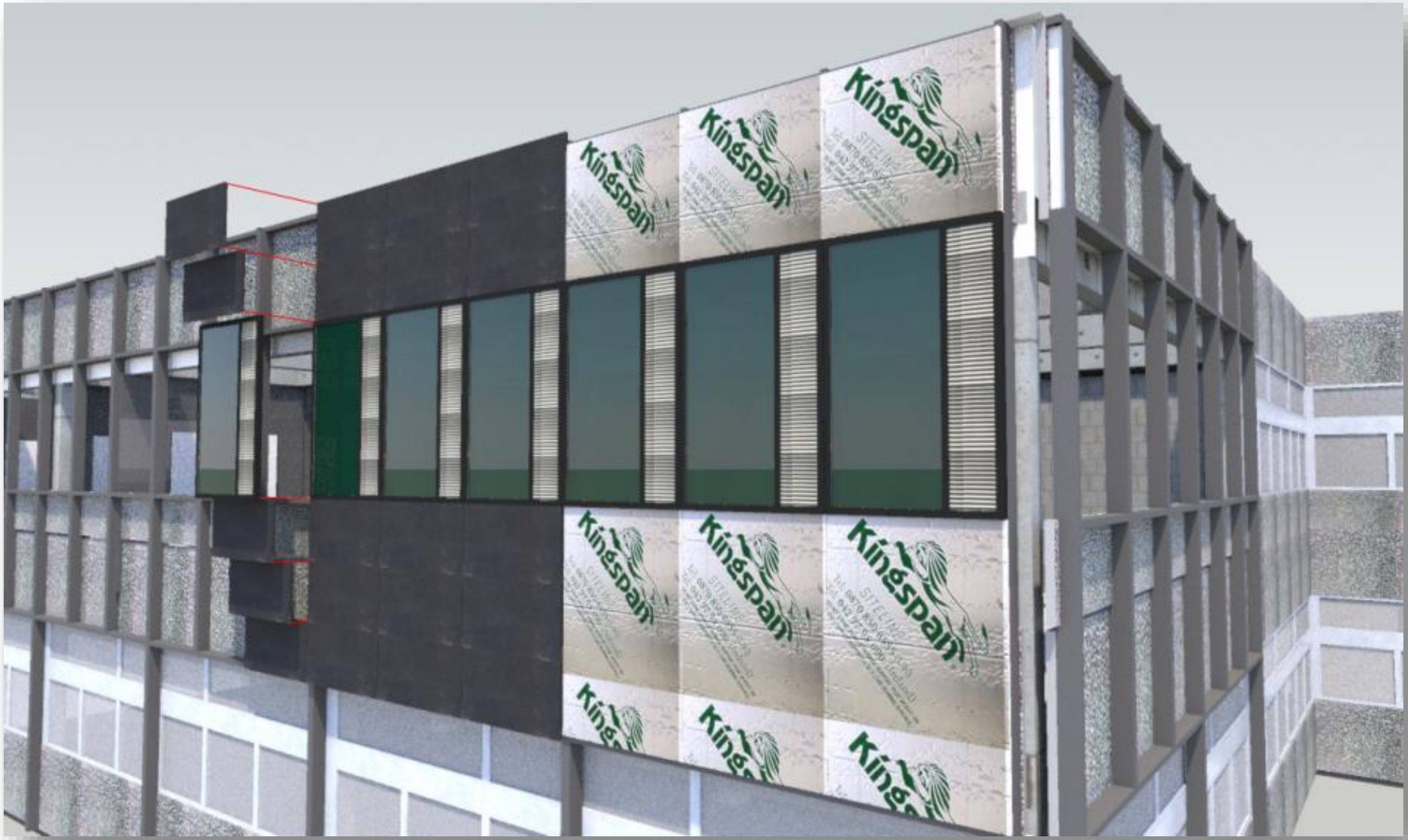
However, the College did not wish to disturb the existing cladding as this would cause internal disruption and additional cost to internal servicing.

A modular but differing façade to each elevation was considered for research purposes. This would address façade orientated specific solutions for heat/solar gain and shading.

Translucent insulated facades were considered but again clashed with the college's wish to minimise abortive costs.



Overall Envelope Design Methodologies:



- limiting heat loss & high level of air tightness
- Reduce active mechanical
- scalable in a modular
- natural ventilation, occupancy control and use of the existing concrete massing.

Fabric And Envelope

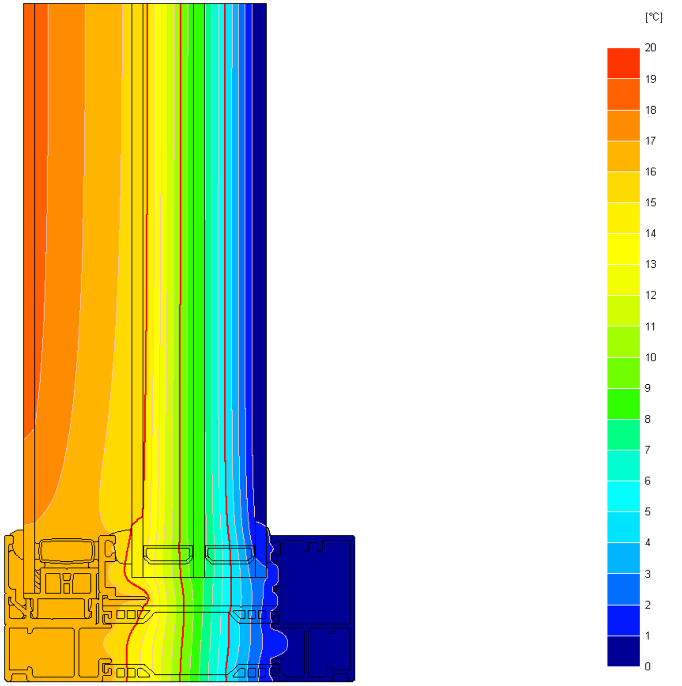
Passive design techniques:

- Curtain wall with 125 mm Kingspan exterior insulation U value of 0.15 w/m2K.
- Point thermal bridges were avoided
- roof was externally insulated with 200mm elemental U value of 0.10 w/m2K.

Fabric And Envelope

Passive design techniques:

- Quadruple glazed window used was elemental U-Value of 0.85 w/m2K.
- Infiltration ACH of between 0.2 and 0.3 were being targeted
- Daylight balancing
- Thermal bridges were minimised



Towards a low energy Retrofit

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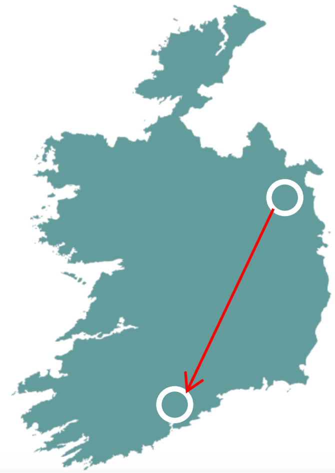
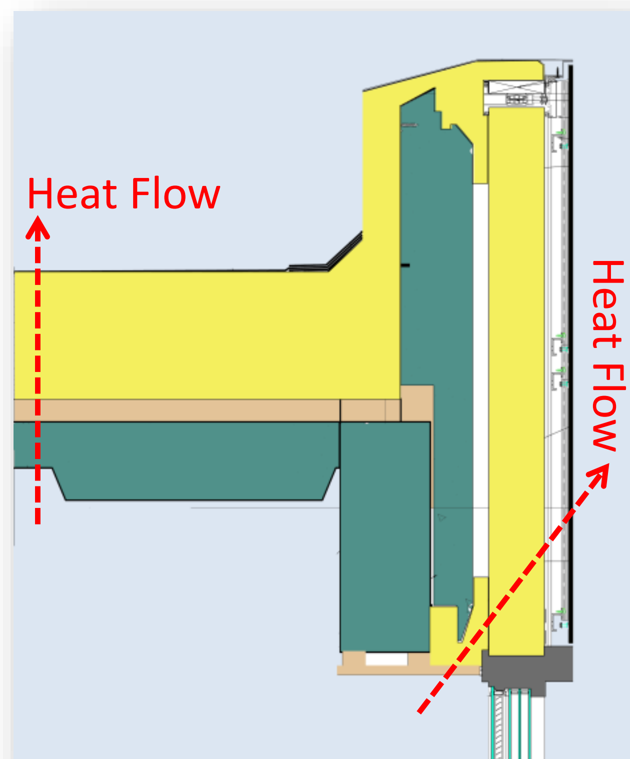
Manufacturing Design Solution

- Low embodied energy
- High economic return to local industry
- AMS thermally broken curtain wall and window section
- Kingspan supports project with insulation
- Curtain wall is hooked over the existing parapet and supported from the ground.
- Localised fixings
- Absence of penetrations
- Avoids shearing forces and thermal bridges.





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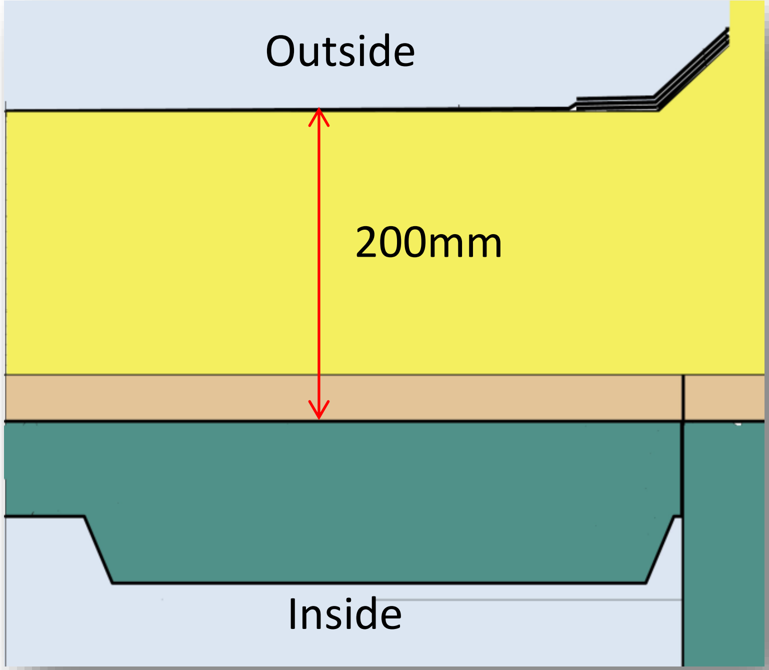
Manufacturing Design Solution

- 200 mm of insulation were applied over the existing roof finish
- Existing glazed ration 37% glazed / 63% solid
- New fenestration ratio 16% glazed / 84% solid
- Average U value rises



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Humidity and Moisture

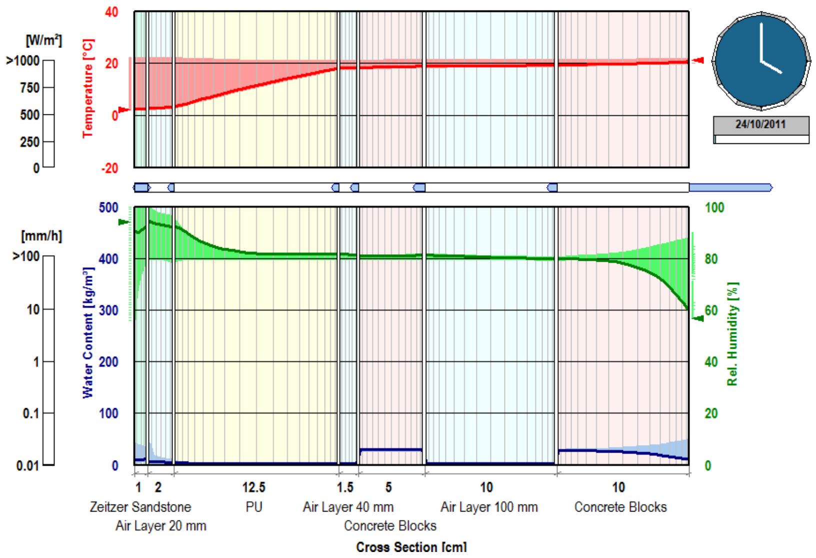
Existing porous aggregate concrete resulting in moisture transfer.

A hygro-thermal analysis shows a high moisture transfer in conjunction with a high ventilation

Simulation modelling-WuFi

Refit might cause dew point movement.

Avoid critical surface humidity and interstitial condensation.



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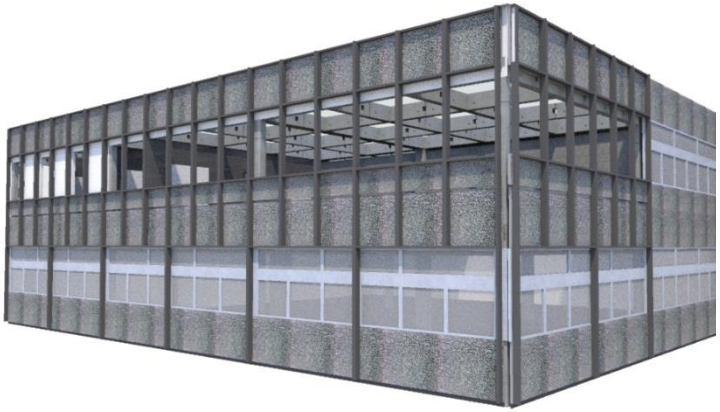
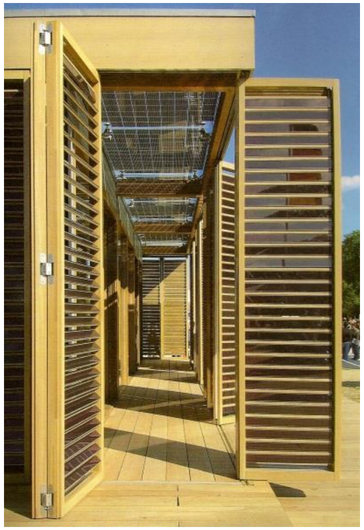
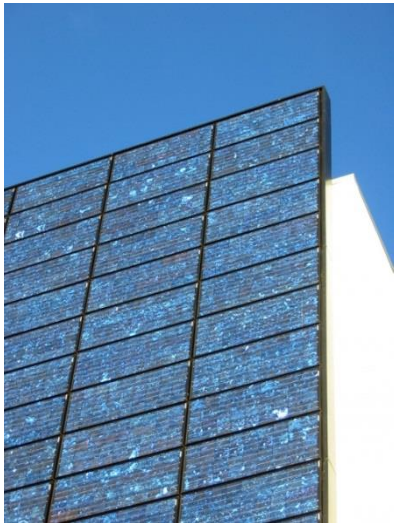
Manufacturing Design Solution

- Solution needed to be modular
- Fast offsite construction or assembly
- Curtain wall =scalability with the minimum of disruption.
- This would allow the use of Building Integrated Photovoltaic at a later point.
- It also mitigated against possible fabric degradation an decoration.



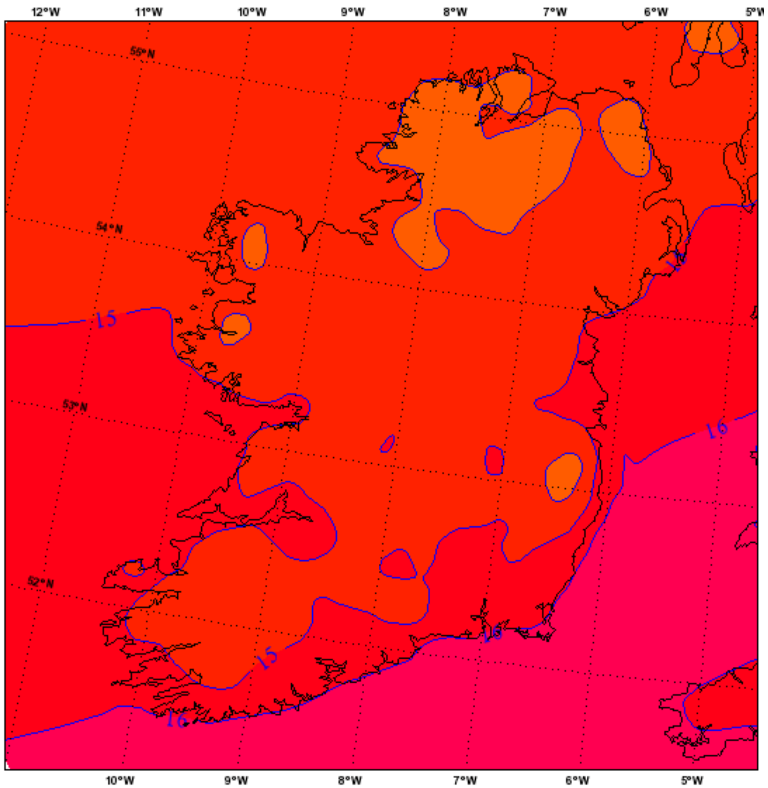




The Next 30 Years of CIT Main Building……

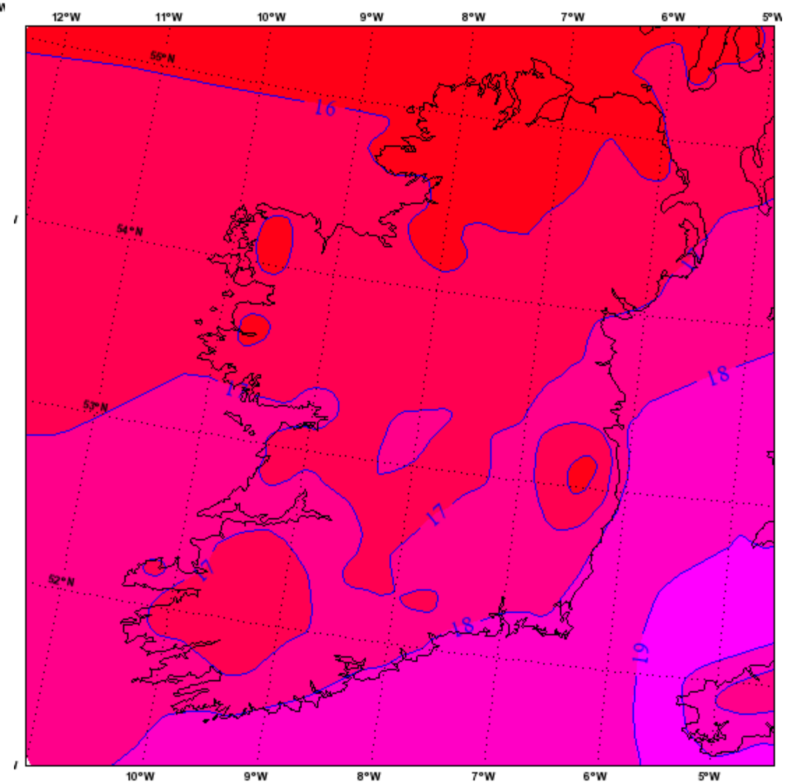
- Lower Heating Loads
- Higher Risk of Overheating

RCA(HADLEY-A1B High Sens) 2 m Temperature (C°)
Monthly average Aug 1961-2000



Average Temperature Cork = 15-16°C

RCA(HADLEY-A1B High Sens) 2 m Temperature (C°)
Monthly average Aug 2021-2060



Average Temperature Cork = 17-18°C

C4i Consortium (Met Eireann & UCD) (www.c4i.ie) non probabilistic climate change projections for Ireland (no uncertainty built in to models):

There is a predicted warming of between 1.5 – 3.0degC across the country by 2050.

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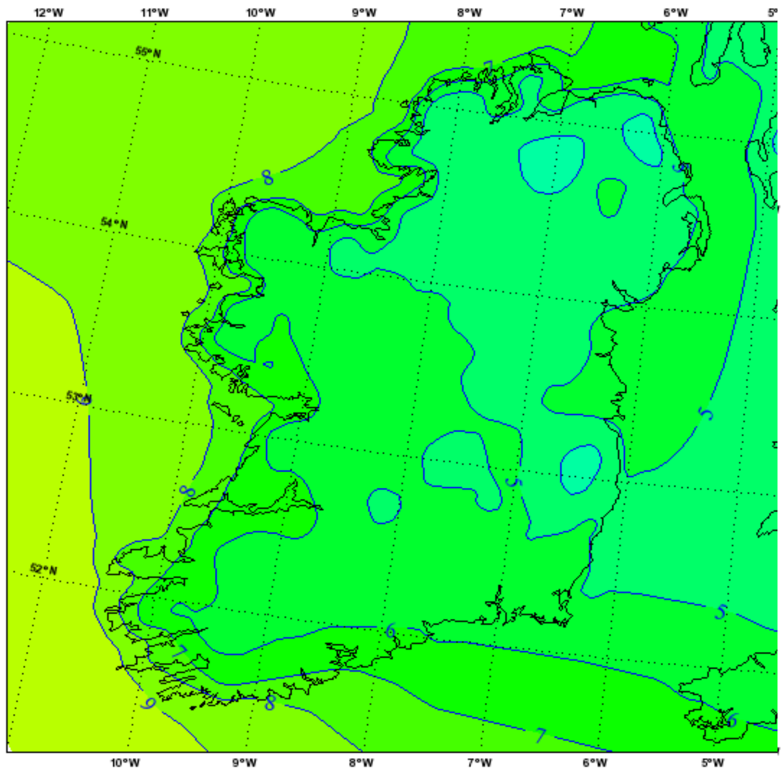
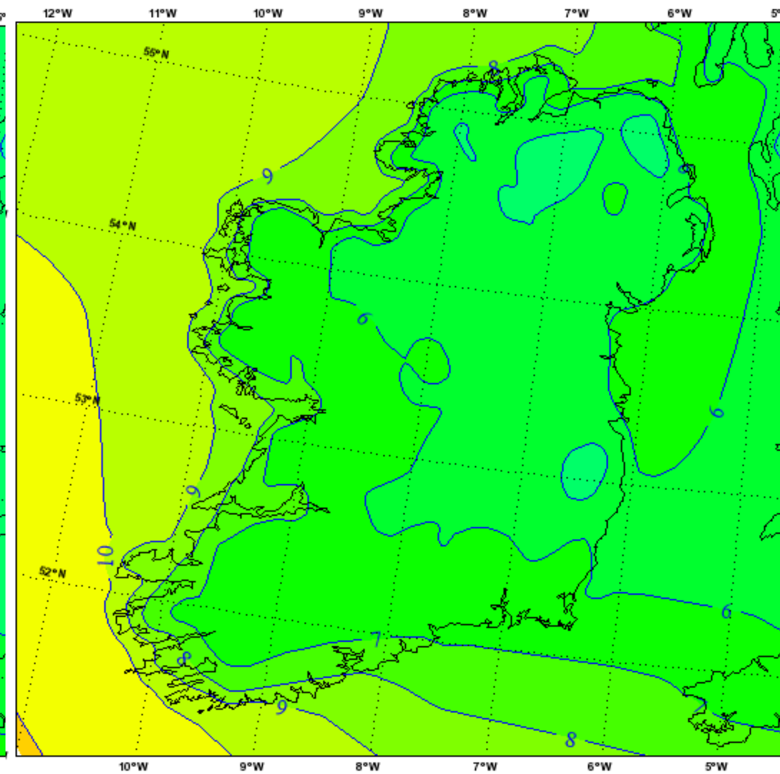
RCA(HADLEY High Sens) 2 m Temperature (C°)
Monthly average Jan 1961-2000



Average Temperature Cork = 6°C

RCA(HADLEY High Sens) 2 m Temperature (C°)
Monthly average Jan 1961-2000



Average Temperature Cork = 7-8°C

C4i Consortium (Met Eireann & UCD) (www.c4i.ie) non probabilistic climate change projections for Ireland (no uncertainty built in to models):

There is a predicted warming of between 1.5 – 3.0degC across the country by 2050.

Current Situation – Energy Use

In 2009

- Annual Heating energy demand was measured @ **263kWh/m^2** ,
- Annual Electrical energy demand was measured @ **110kWh/m^2**,
- Total of 373 kWh/m^2 (Purcell 2010)

(SEAI 2006)- Average total energy consumption:

- in a university building is **253kWh/m^2/yr**
- in an IoT building **228 kWh/m^2/yr**

ECG19 Type 1 Building

- Annual Heating Demand **79 kWh/m^2/yr**
- Annual Electrical Demand **33 kWh/m^2/yr**

The heating is primarily delivered through perimeter radiators without TRVs powered by Gas boiler. There is a predefined heating system time schedule with no space temperature

Advances in low energy lighting have been introduced and a CHP system is being considered for primary heating. There is localised air conditioning and fresh air delivered throughout the building.

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PRD – Energy Use

In 2012

- Annual Heating energy demand is targeted @ **< 35 kWh/m²/yr** ,
- Annual Electrical energy demand was measured @ **<30 kWh/m²/yr**
- Total of **< 65 kWh/m²/yr**

How ?

- Fabric & envelope
- Passive ventilation & space cooling
- High efficiency lighting
- Renewable energy sources
- Informed occupants
- Smart metering, monitoring and controls
- Information & data informed energy management

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PRD Environmental Control – High Level Strategies

Requirement	Method	Notes
Ventilation	Natural Occupancy Driven	(automated vents for min BRegs requirement)
Cooling	Automated Thermally coupled natural convection & fabric energy storage solution	Sensible TES currently – Latent TES PCM in future
Heating	Low Temp Heating – Air Source Heat Pump in air-water mode	New radiator installation with T_{flow} water @ 35°C
Lighting	LED fittings in certain section with T5 as balance	Assessing performance of T5 versus LED for occupancy comfort
Power	Grid Electricity	PV connections in future
Controls	Full energy management capabilities in place	Cylon system with automated louvre system incorporated
Monitoring & Metering	Full Parametric Data Logging and sub circuit energy metering	Full diagnostic capability independent of BMS

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UA Value Comparison (Envelope Elements)

Building Element	Area	Existing (Pre Bregs)		Area	PRD74	
		U (W/m^{2}k)	UA (W/K)		U (W/m^{2}k)	UA (W/K)
External Wall	136.30	**0.80**	109.04	183.00	**0.16**	29.28
Fenestration	**81.40**	**6.00**	**488.40**	**34.83**	**0.85**	**29.61**
Roof	247	**1.4**	345.8	247	**0.2**	49.4
Roof Light	6	**6**	36	6	**2.2**	13.2
Total UA Value (Fabric / Envelope)	470.70	979.24		470.83	121.4855	
Ventilation Element	Volume	N	UA Value	Volume	N	UA Value
Ventilation (Infiltration)	741	2.5	616.88	741	0.2	49.35
Ventilation (Infiltration) in L/sec		514.58			41.17	
Average overall UA Value (kW/K)		**1.5961**			**0.1708**	

A potential 90% improvement in thermal transmittance and infioltration losses based on detailed design

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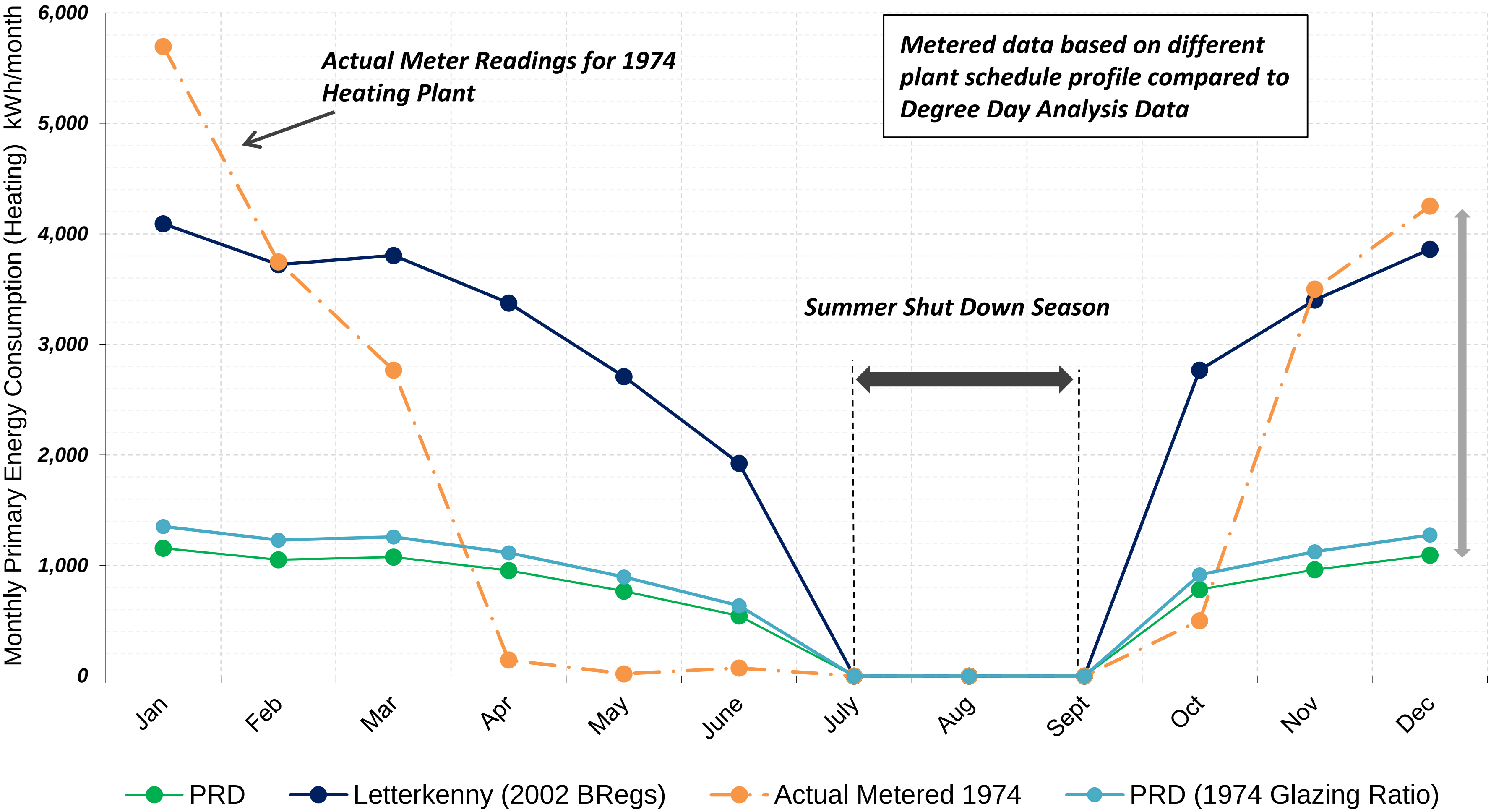
Towards a low energy Retrofit

11/11 for 20/20

Average Monthly Primary Energy Heating Demand (PRD Space only) (247m² B-Block)



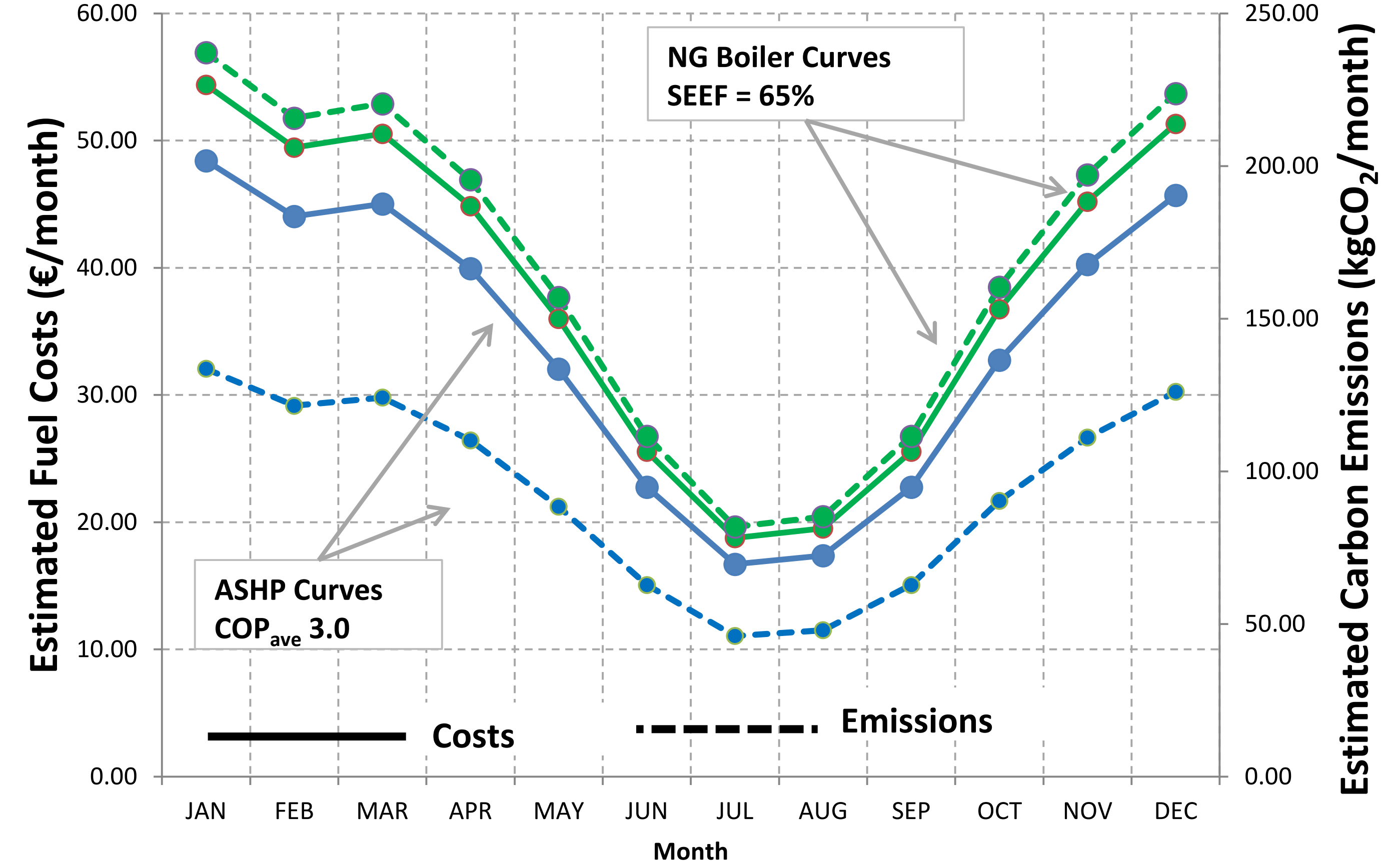
Summary Findings

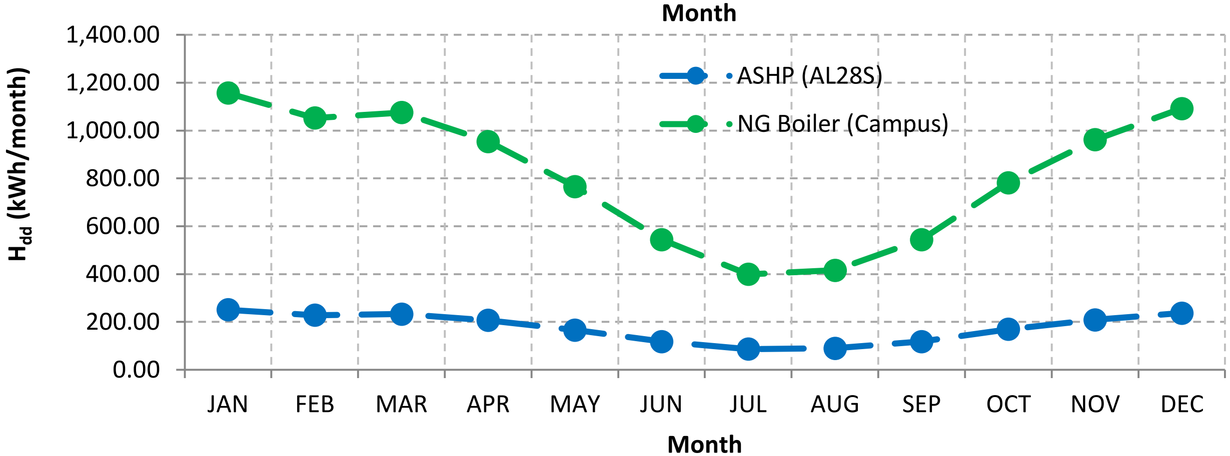
- The heating system operation schedule has an influence on energy consumption
- Incorrect to compare current energy use to predicted performance
- Equity payback on investment in envelope costs should not be based on heating system improvements alone
- Part completion of B-Block envelope leads to inefficiencies which may not reflect actual performance of scaled project

Solution	KPI
Actual	85 kWh/m²/yr
PRD	30-35 kWh/m²/yr
H_{dd} Existing	260 - 320 kWh/m²/yr

How Will Actual System be controlled compared to current operation ??

Technology Comparision Fuel Cost & GHG Emissions





Summary Findings

- COP ASHP crucial (<2.5 unfeasible)
- Average 44% reduction on GHG emissions with using ASHP
- Average 11% reduction in fuel costs using electricity based heating with SCOP 3.0

Dimplex L28AS ASHP
T_{water} = 35°C
T_{air} = 2-7°C
Fuel Costs SEAI
c/kWh Elec = 19.32
c/kWh Gas = 4.7

How Will Actual System Perform ??? !!!

Towards a low energy Retrofit

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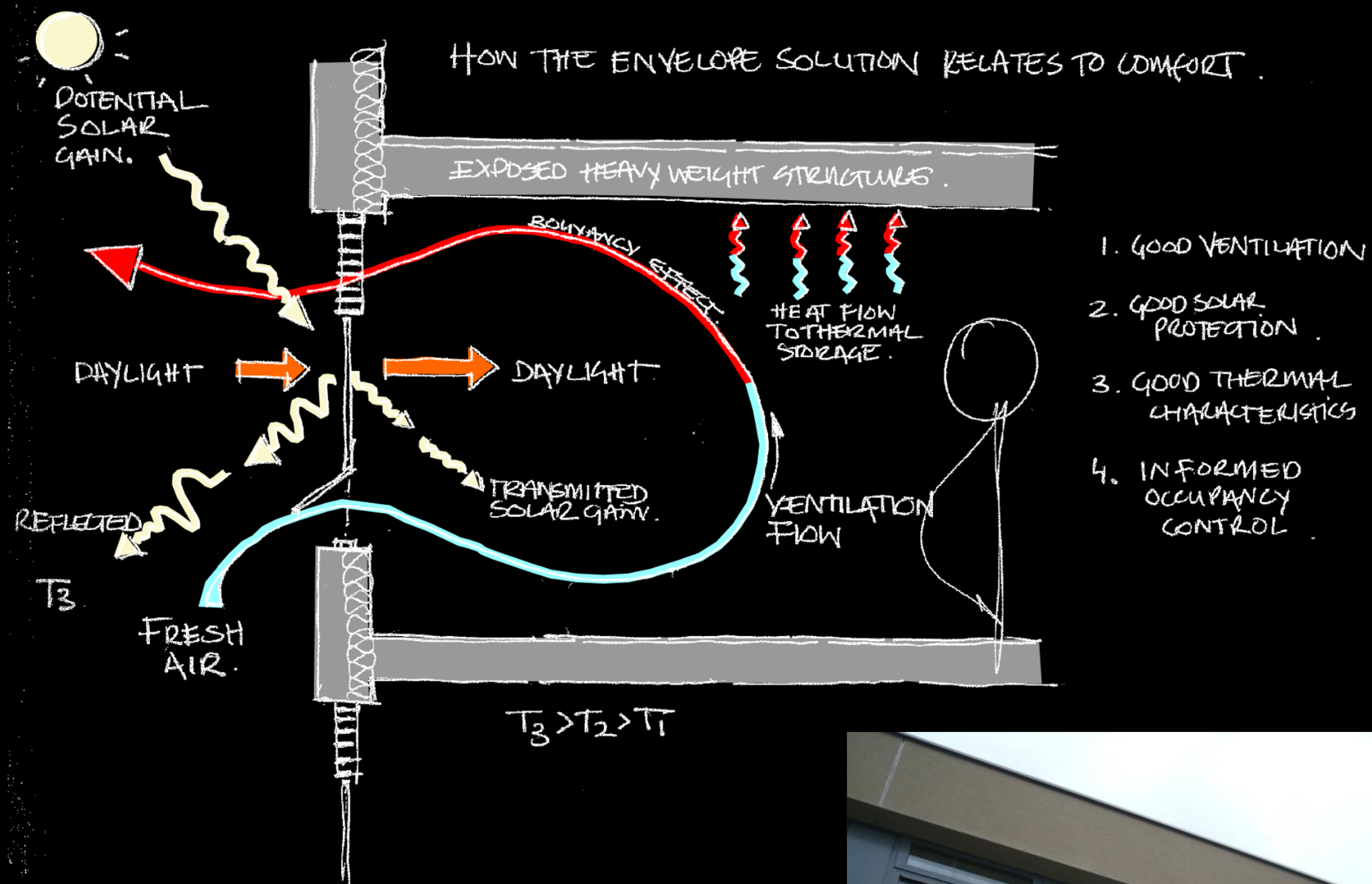
Ventilation Strategy



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11/11 *for* **20/20** *Towards a low energy Retrofit*

Ventilation Strategy

CIT team project brief was for a passive solution to ventilation and space cooling as:

1. Project to act as pilot for wider building
2. Project to act as examplar project for public sector buildings retrofit
3. Irish maritime climate suitable to passive techniques if implemented correctly

Design Strategy

Requirement / Objective	Design Decision
Satisfy psychological element to occupancy comfort through personal control of environment	manually operable ventilation doors and manually operable interstitial blinds for glare and solar protection
Satisfy dynamic response of space to transient climate through use of thermally coupled ventilation	automated high level louvred sections allowing diurnal recycling of heat build up throughout the day; time lag on peak internal temperatures; direct gain storage of solar radiation during winter
Utilise whole building energy simulation software to model bulk airflow and provide performance requirements to enveloped specialist	Engage IES for daylighting simulation, airflow analysis, fabric analysis
Provide a high performance filter for fenestration strategy- lead to a quadruple glazed interstitial blind solution (research orientated solution)	Provide high performance U Value beyond current installed technologies; provide good solar protection; utilise external or interstitial shading techniques; avoid internal shading where possible (south and west facades)

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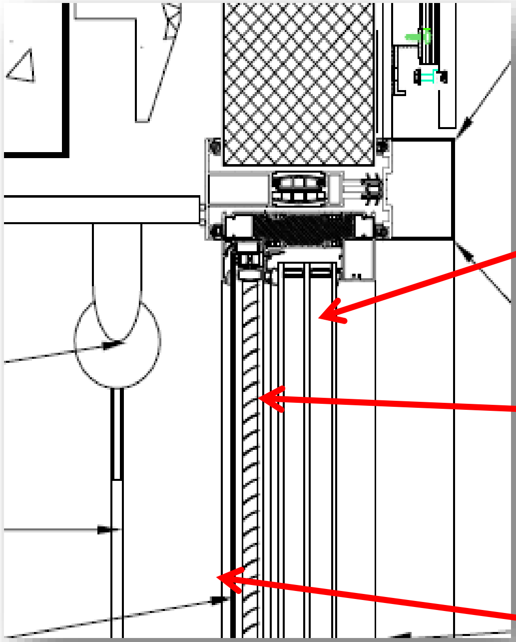
Ventilation & Fenestration Solution



Sealed Triple Glazed Element

Excellent external climate filter
Excellent conductive performance
Excellent irradiation transmittance performance

Interstitial Blind

Manually operated no automated element
No physical contact wit internal space
Expensive solution

Internal Separation Glazed Element

No inefficiency in absorption and emission of radiation energy
No opportunity for damage and dust collection

Glazing Specification

South & East Elevations
IC Low – E
Composition (40mm) 6-12-6-12-6 (S3) Krypton

Ug-value	**0.5**
Light Trans	**70%**
g-value	**0.49**
L_{rout}%	18

North Elevation
Suncool 70/40
Composition (40mm) 6-12-6-12-6 (S3) Krypton

Ug-value of	**0.5;**
Light Trans	**63%**
G value	**0.38**
L_{rout}%	18

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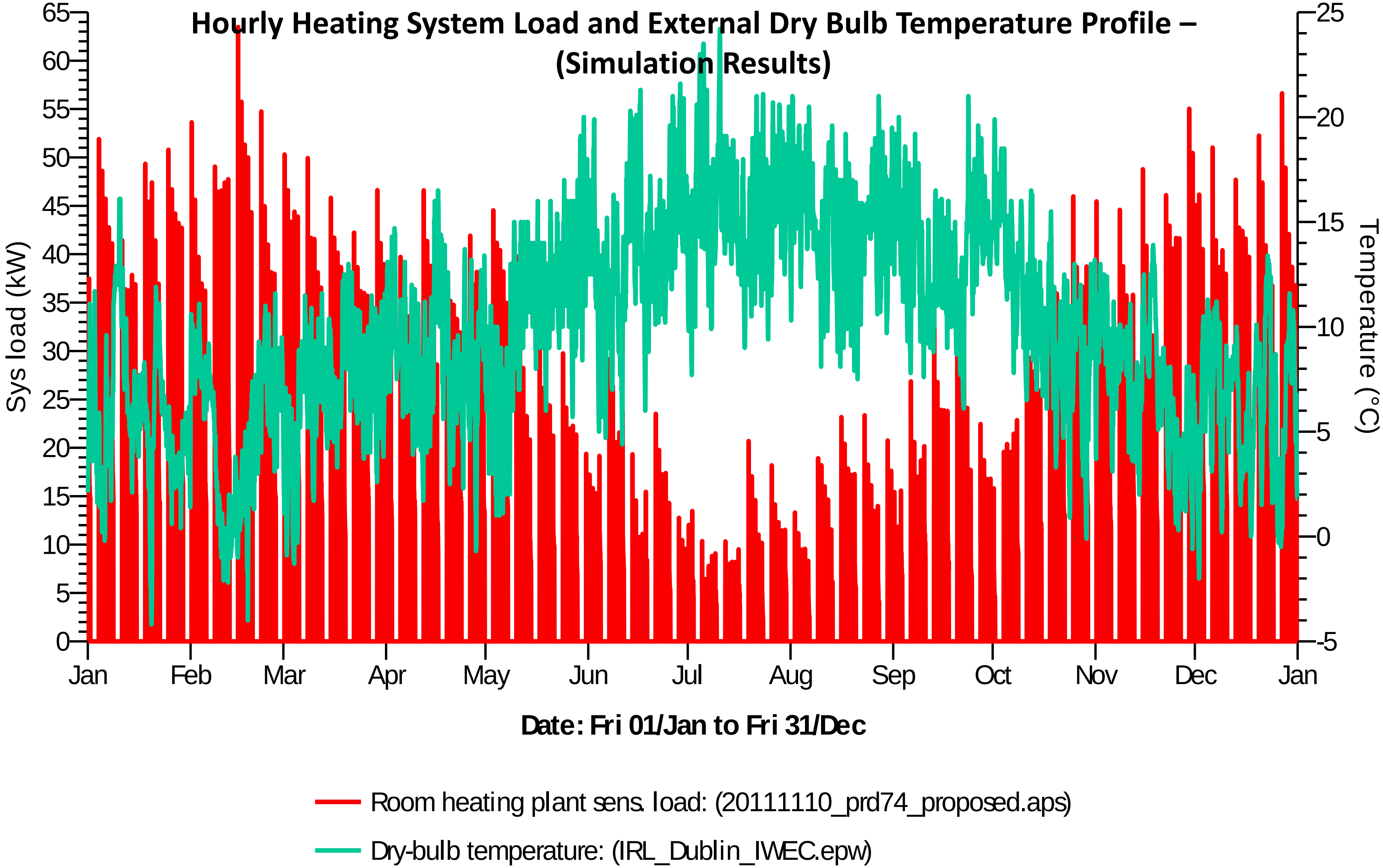
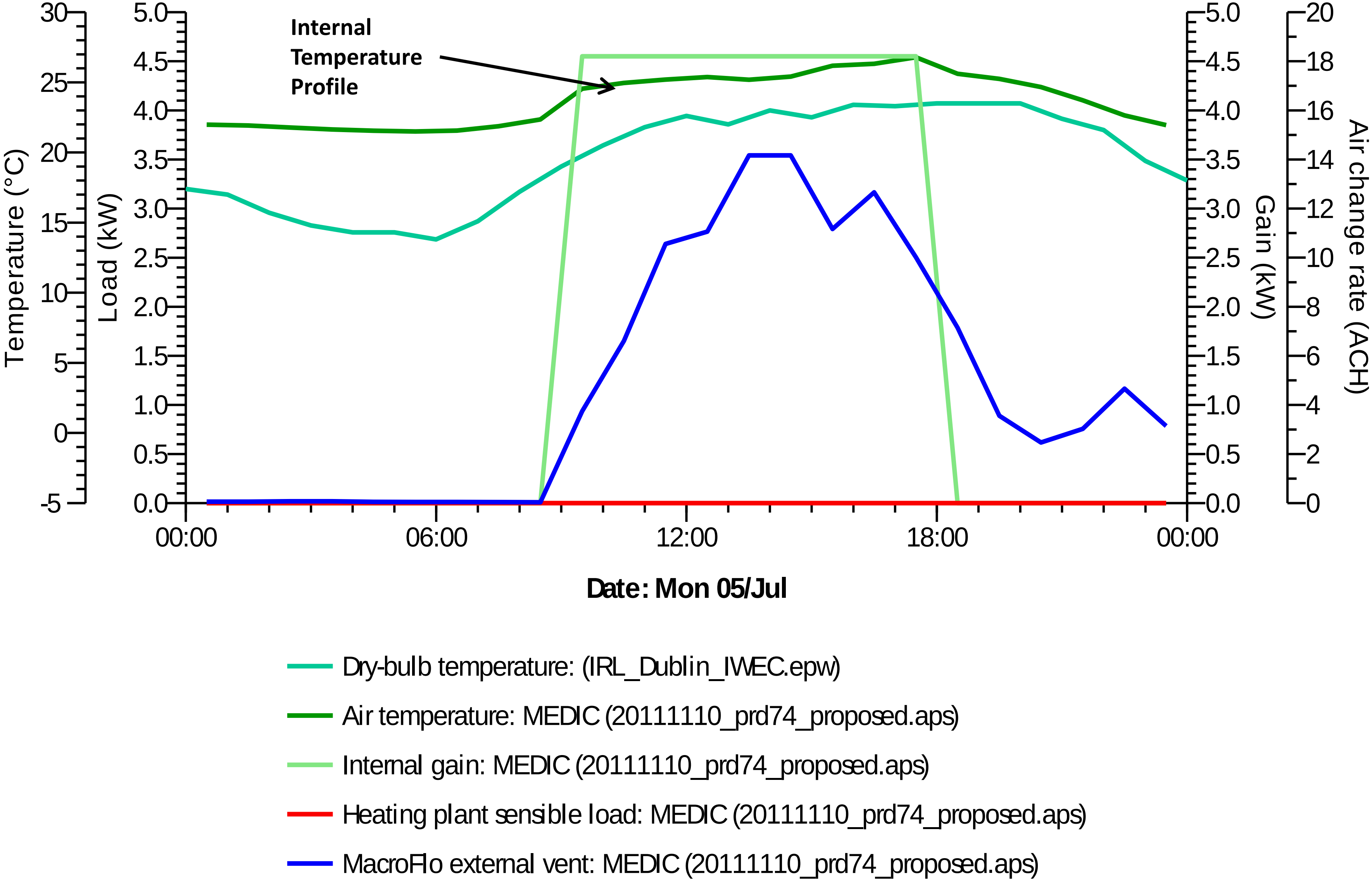


Summary Simulation Findings

- Some high heating values showing in winter months (upwards of 65kW)
- May be due to variable settings in model
- Also factors in energy transfers between PRD space and ground floor, adjacent first floor
- Challenge for research team will be to correlate actual performance with modelled performance

Summertime Overheating Risk Assessment – (Simulation Results)



Summary Findings

Data based on performance on a single July day

$T_{space\ peak}$ = 26.78°C

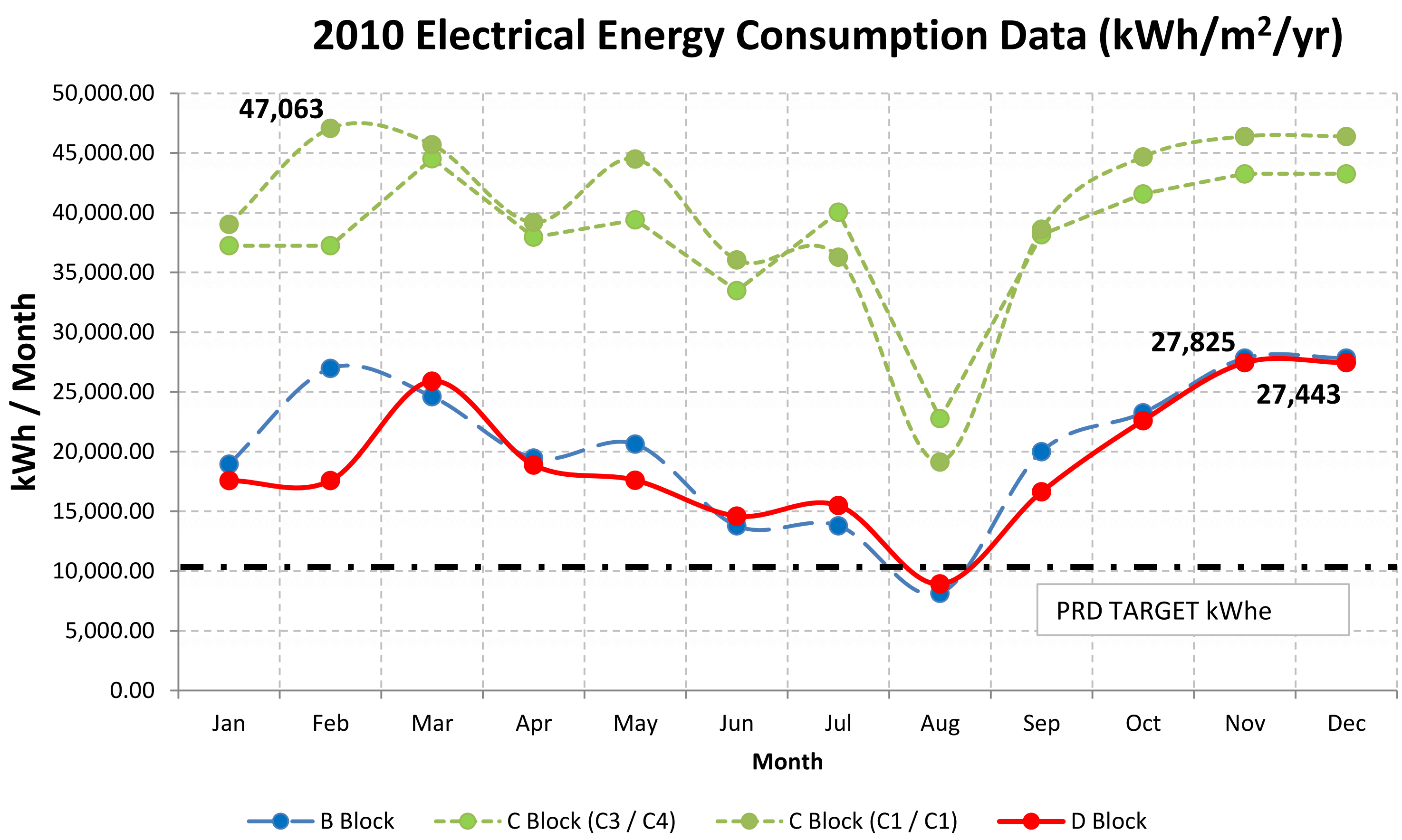
Vol_{peak} = 14 ACH

No of Hours above 25°C = 27hours

Towards a low energy Retrofit

11/11 ***for*** **20/20**

Existing Electrical Energy Usage (Historical)



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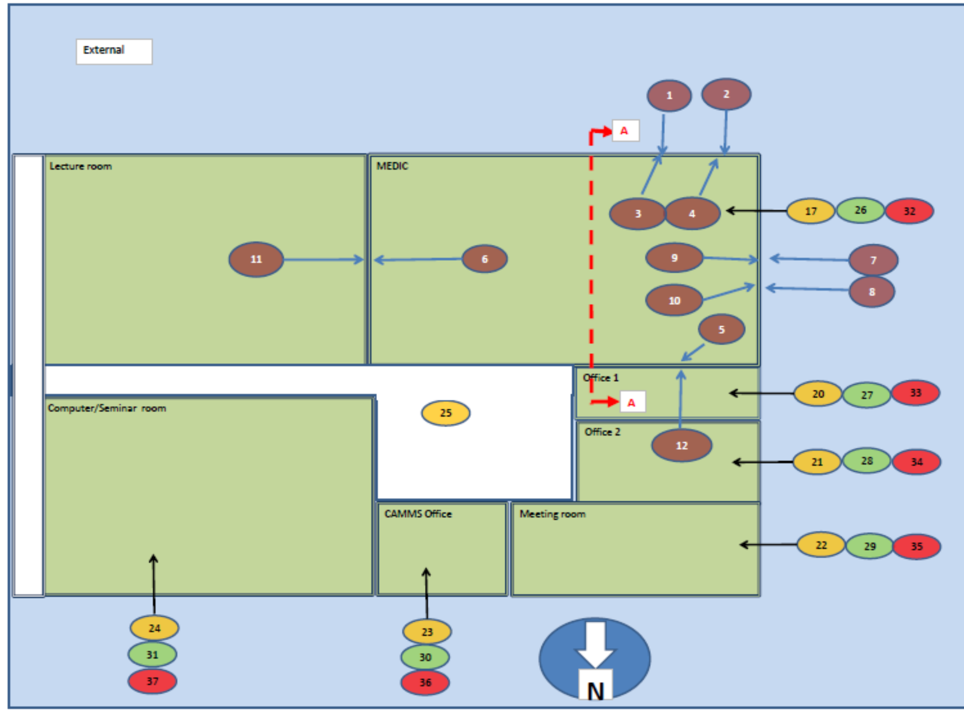
11/11 ***for*** **20/20**

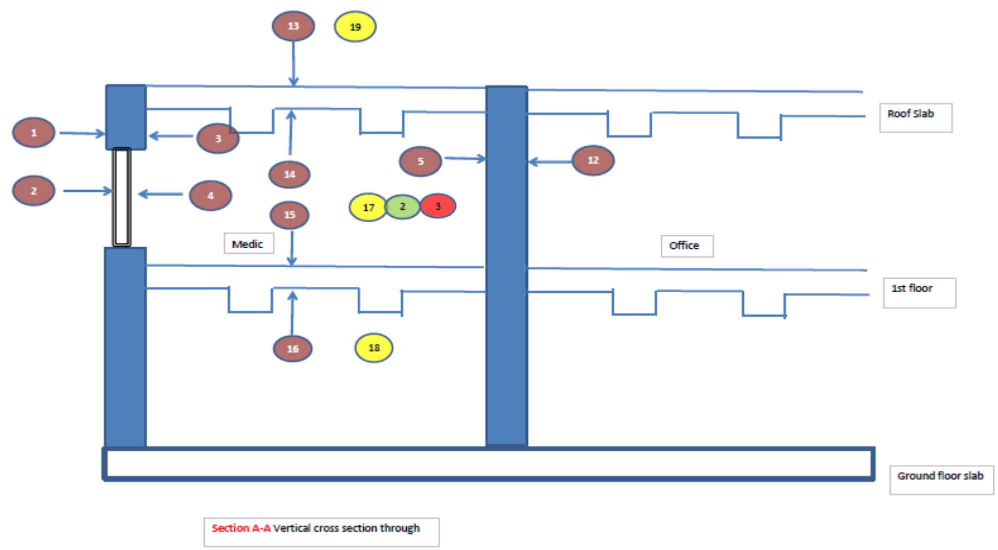
Monitoring at PRD

What Parametric Monitoring will take place?

Through the use of radio frequency wireless data logging equipment, both embedded and surface mounted a range of parameters will be monitored:

- **Ambient air temperature and humidity**
- **Radiant surface temperatures**
- **Daylight levels**
- **Artificial Light Lux levels**
- **Air flow velocities (TBC)**
- **Envelope thermophysical properties**
- **Energy consumption**
- **Appliance energy usage monitoring**
- **User satisfaction feedback and human comfort**
- **Occupancy usage patterns and satisfaction**
- **Resource usage patterns**





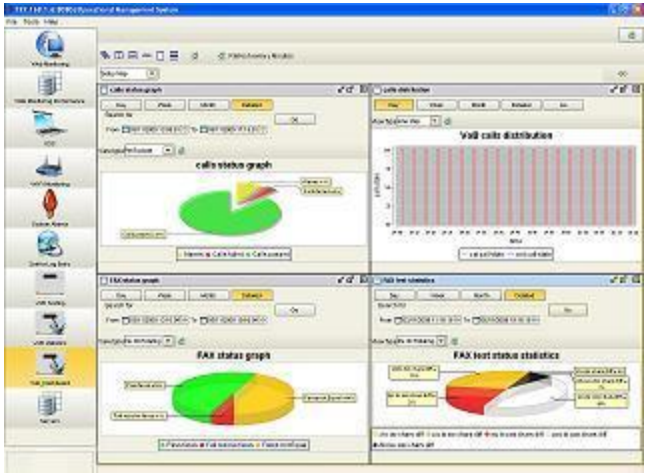
Towards a low energy Retrofit

11/11 ***for*** **20/20**

Test Bed Capacity

- **Maximise potential for data harvesting and analysis** of energy performance of retrofit
- Create a live lab testbed environment for energy in existing building stock
- An inherently flexible solution, **easily and readily adaptable to modification** for all aspects of the space.
- An **opportunity to trial, test, monitor and analyse a range of building specific technologies** with emphasis on product and solutions enhancement over time.
- An **opportunity to establish a timeline approach towards zero operational energy** refurbishments of existing buildings.
- A **dedicated controlled, monitored environment with plug and play capability** for industry and academic partners to trial differing technologies.

Provision of a centralised data logging system that will collate upwards of 270,000 data points of information for analysis by post graduate research, industry research partners and undergraduate students



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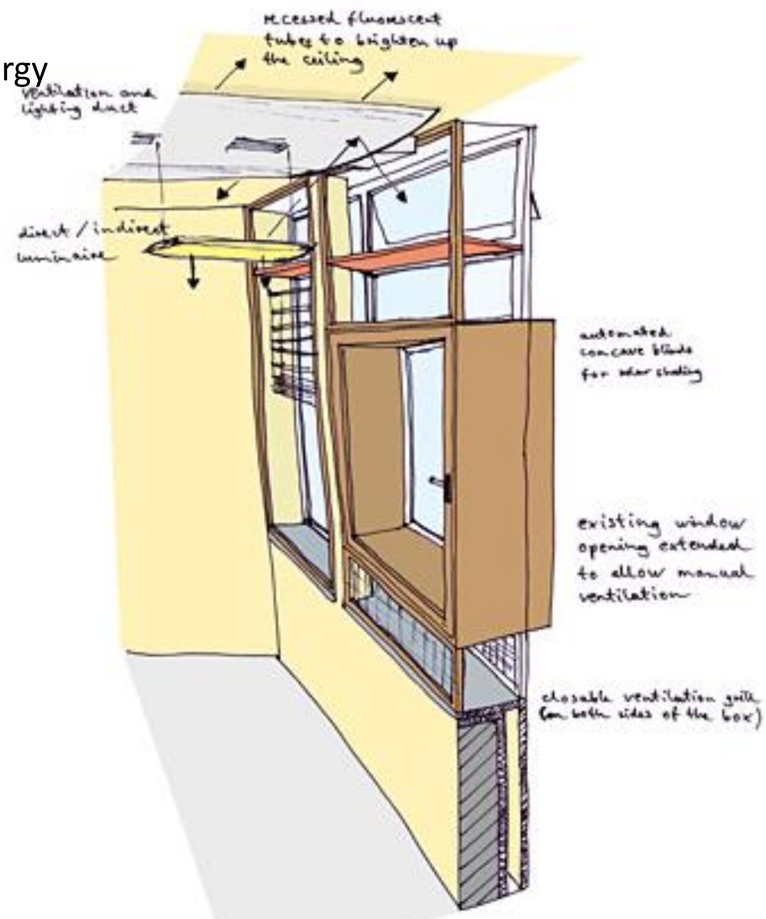
Overall Retrofit Performance

- Targets less than 30 $kWh_{th}/m^2/yr$ primary energy delivered for space heating
- Targets less than 35 $kWh_e m^2/yr$ delivered energy delivered for lighting, power and IT
- Overall average U Value 0.17 W/m^2K
- Using renewable energy sources to supply energy
- Deliver net zero energy space by 2013

Could we do better?

- Passive house is 15 $kWh_{th}/m^2/yr$
- Room for improvement:
- Behavioural change



Towards a low energy Retrofit

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Lessons Learned to date for D Block

Its all about the energy-operational and embodied

A highly insulated low energy building makes sense

Modularity is key to phasing and timing.

Curtain wall allows for seasonal development

The expertise is indigenous.

CIT can aspire to a higher standard both functionally and aesthetically

The buildings lifespan can be extended

Retrofit envelopes is design intensive

Behaviour Change is very important

This could be a solution for the 1974 blocks……

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The proof in the pudding is in the eating…………

Data collection commences March 2012

Thank You