nZero.2020 / **a Realised retrofit example**

MEnS Short Course Brunel University

July 2016

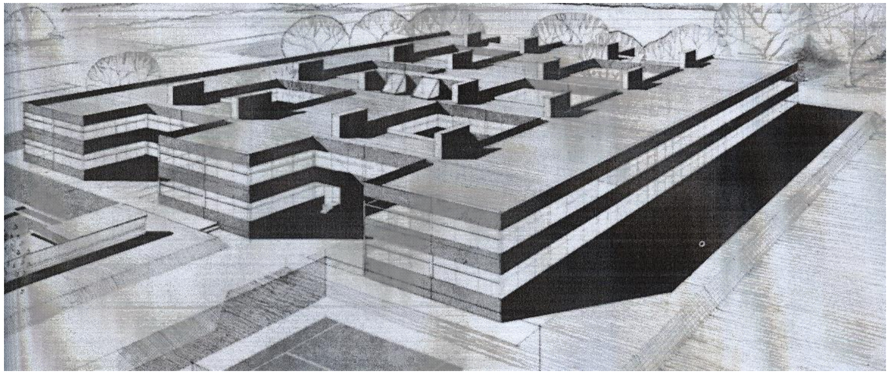
Paul D O'Sullivan / MeSSO //Cork Institute of Technology

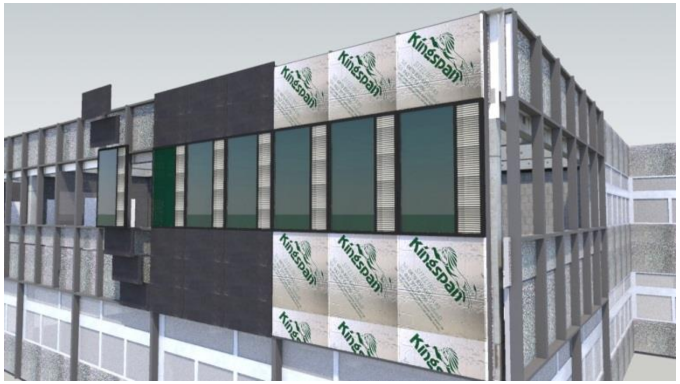
Agenda

1. Introduction & Motivation
2. Specification & Project Build
3. Energy performance
4. Ventilation Rates
5. Overheating Risk
6. Thermal comfort evaluation
7. What are we learning...

nZero.2020 / Introduction

The ‘**Zero2020’ Project** is a project involving extensive refurbishment and upgrade of 3% of an existing 1974 office and teaching space on the Bishopstown Campus of Cork Institute of Technology as a pilot project.

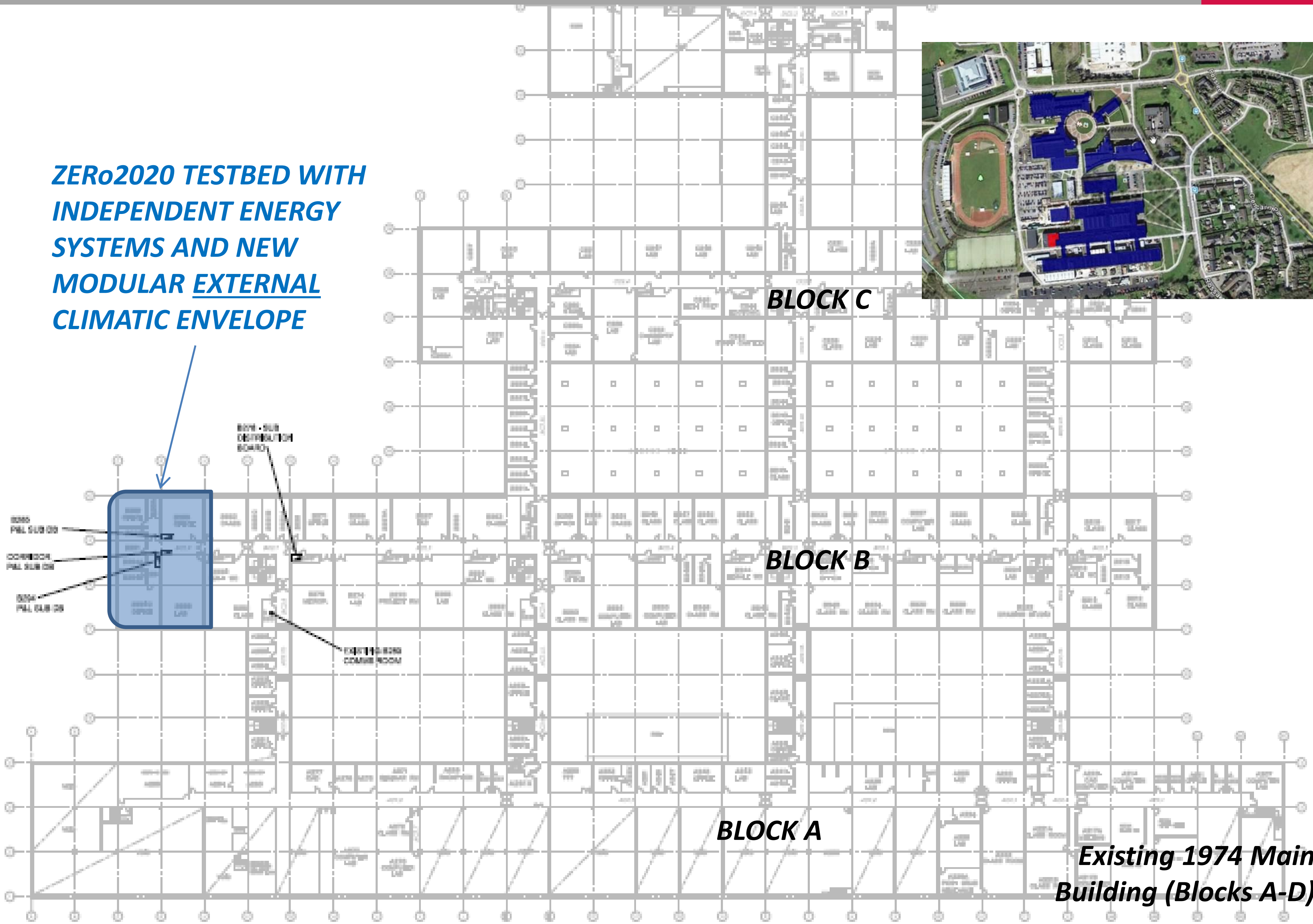




Its mission is to provide a live, monitored testbed environment to explore energy and resource performance through the use of low energy solutions with emphasis on demonstrating nearly zero energy in use operation.

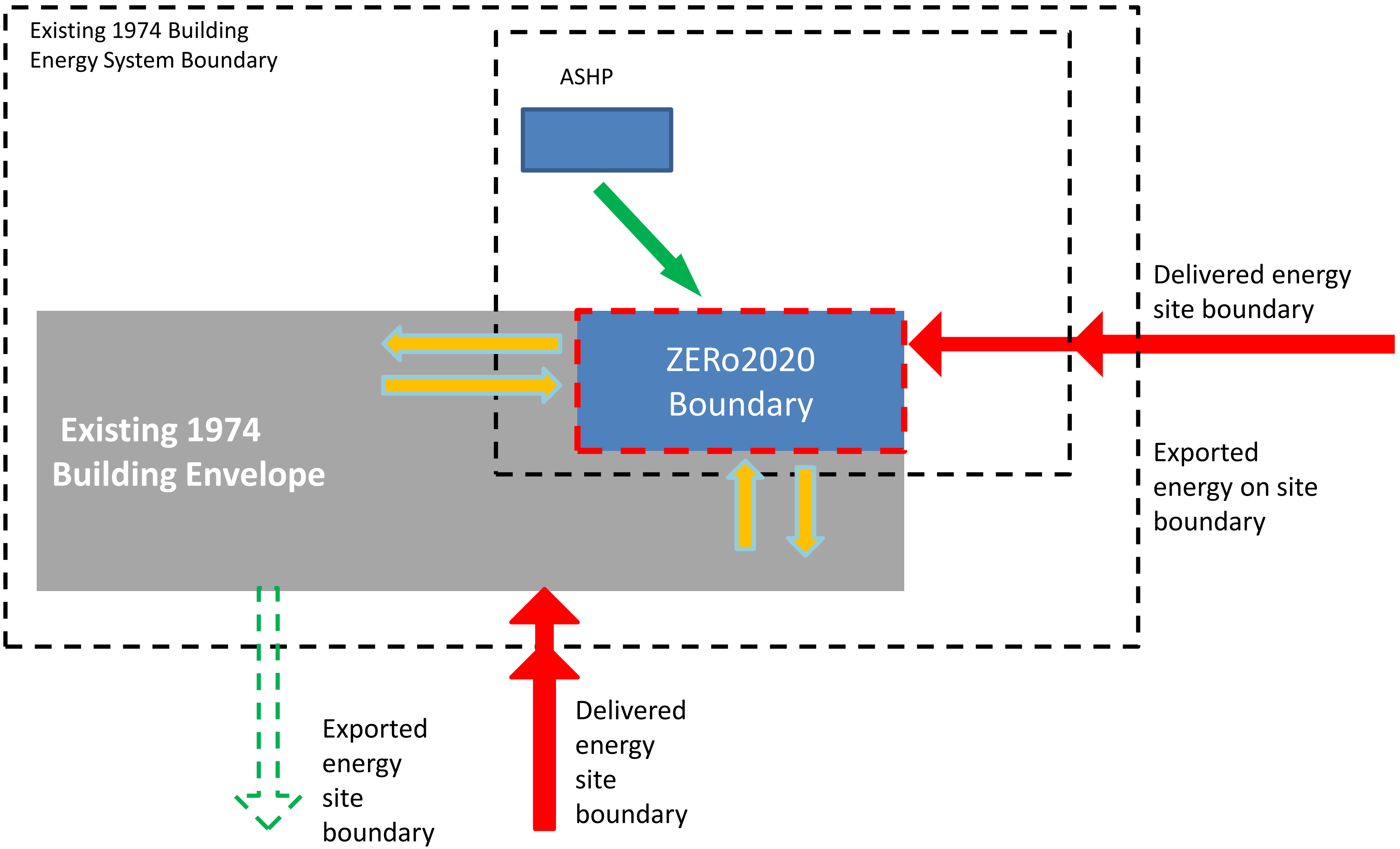
nZero.2020 / Boundary Definition

ZERo2020 TESTBED WITH INDEPENDENT ENERGY SYSTEMS AND NEW MODULAR EXTERNAL CLIMATIC ENVELOPE

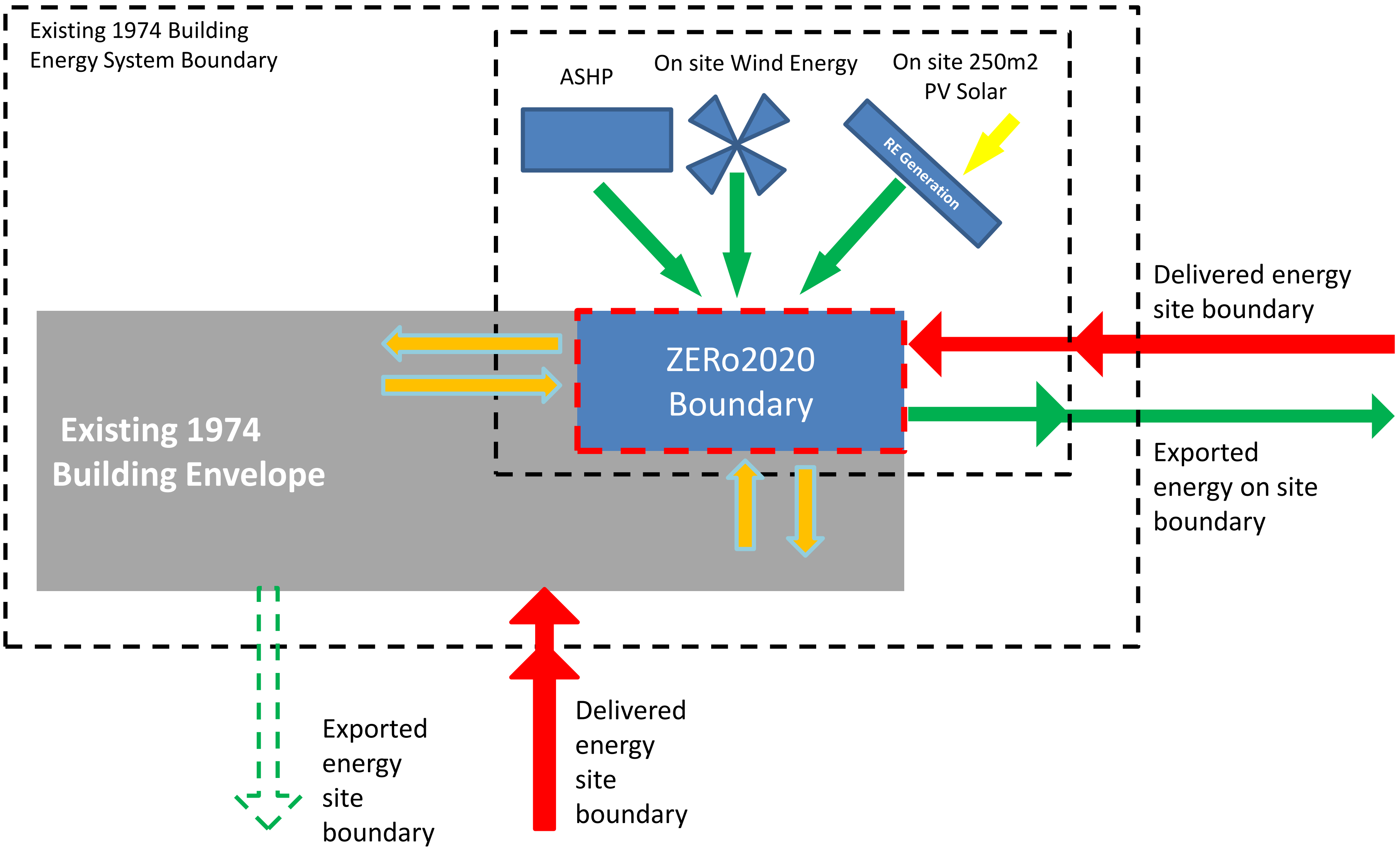


Existing 1974 Main Building (Blocks A-D)

nZero.2020 / Boundary Definition



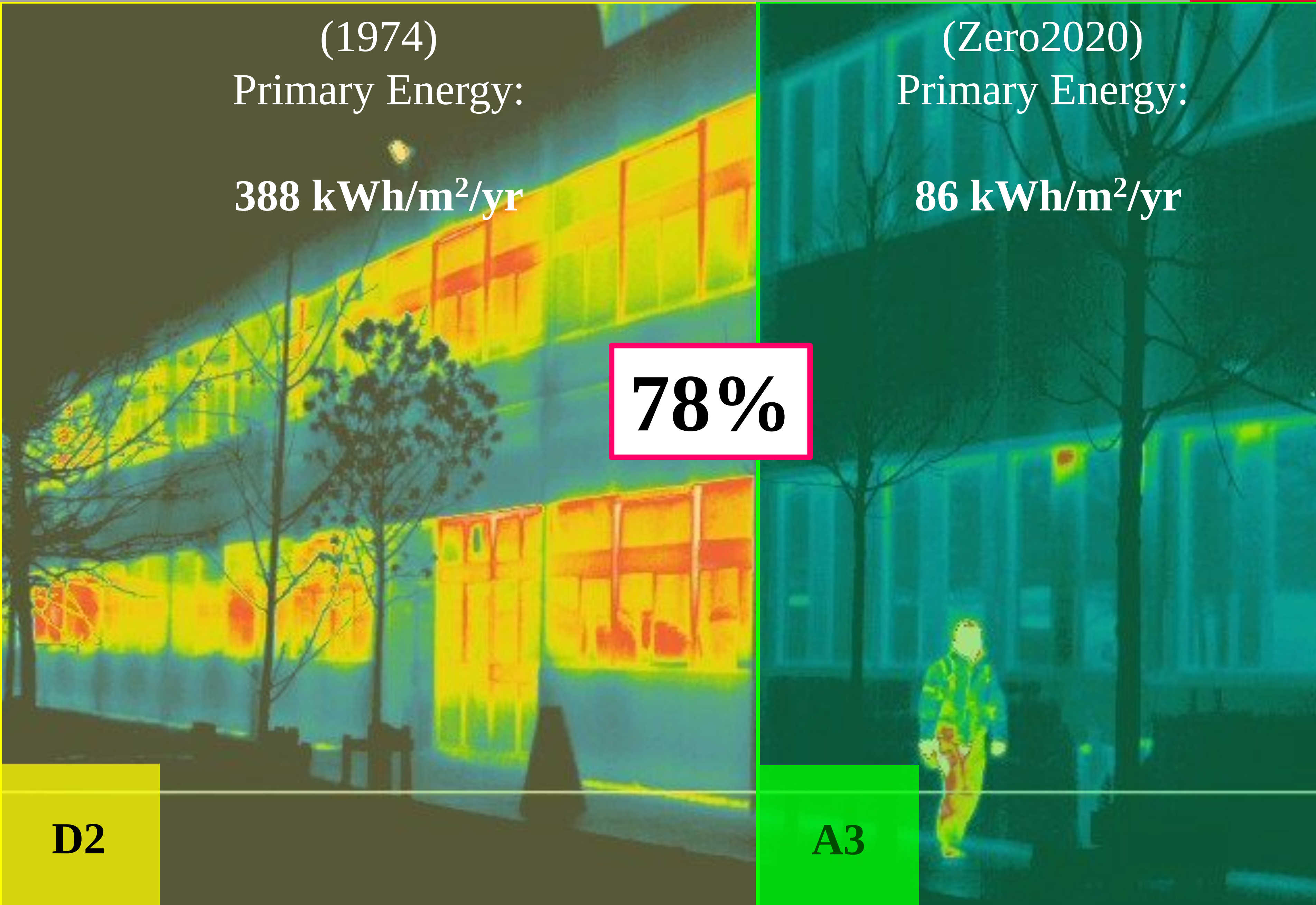
nZero.2020 / Boundary Definition



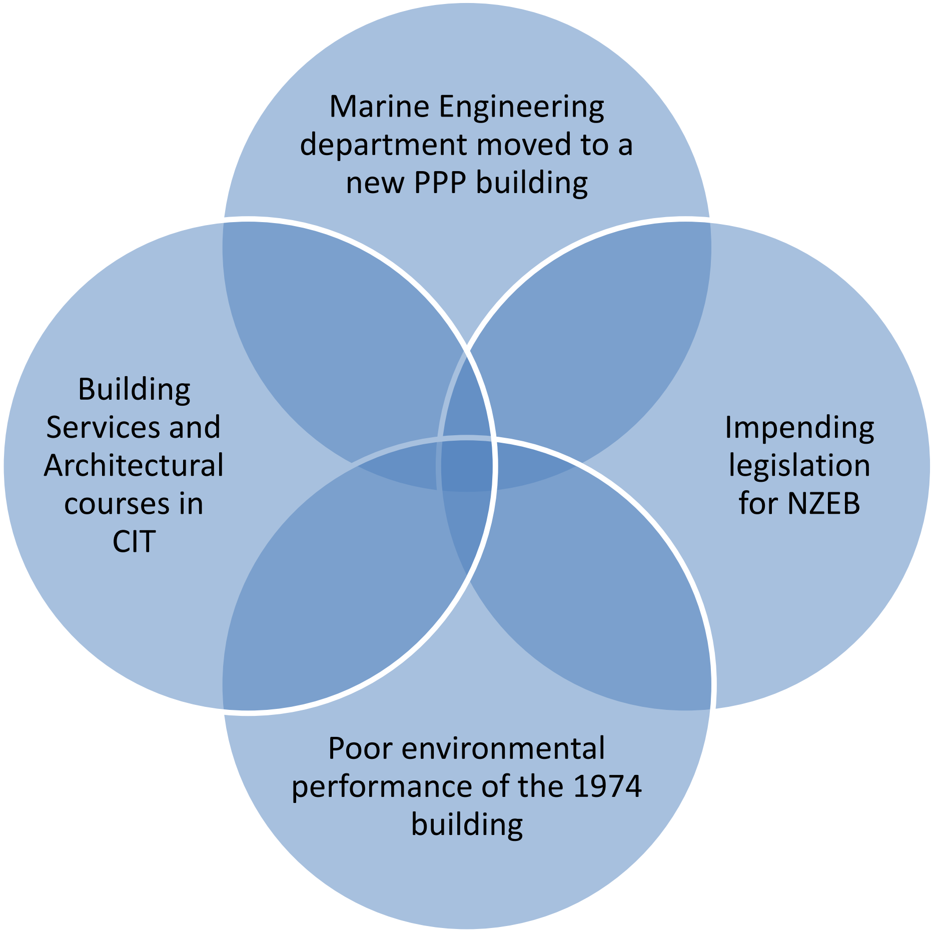
nZero.2020 / Boundary Definition

nZero.2020 / Thermophysical Performance

Component	CIT (1974)	TGDL (2008)	Cost Optimal	Zero2020
Wall U-value (W/m^2K):	2	0.6	0.3	0.09
Roof U-value (W/m^2K):	1.1	0.35	0.15	0.09
Floor U-value (W/m^2K):	0.8	0.8	0.10	0.8
Window U-value (W/m^2K):	>5	2.2	1.8	1


(1974)
Primary Energy:
388 kWh/m²/yr
(Zero2020)
Primary Energy:
86 kWh/m²/yr
78%
D2
A3

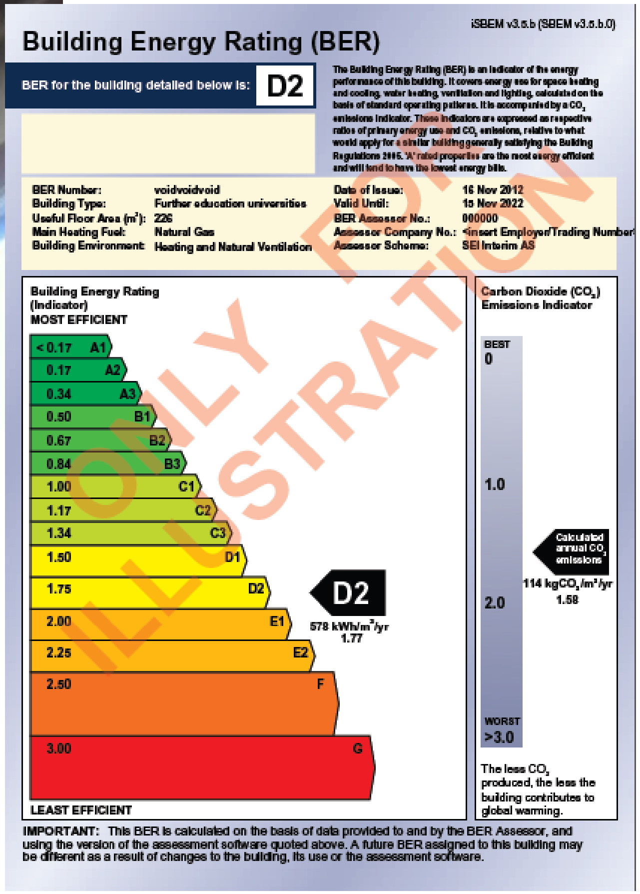
nZero.2020 / Motivation


Marine Engineering department moved to a new PPP building
Building Services and Architectural courses in CIT
Impending legislation for NZEB
Poor environmental performance of the 1974 building

Marine Engineering department moved to a new PPP building

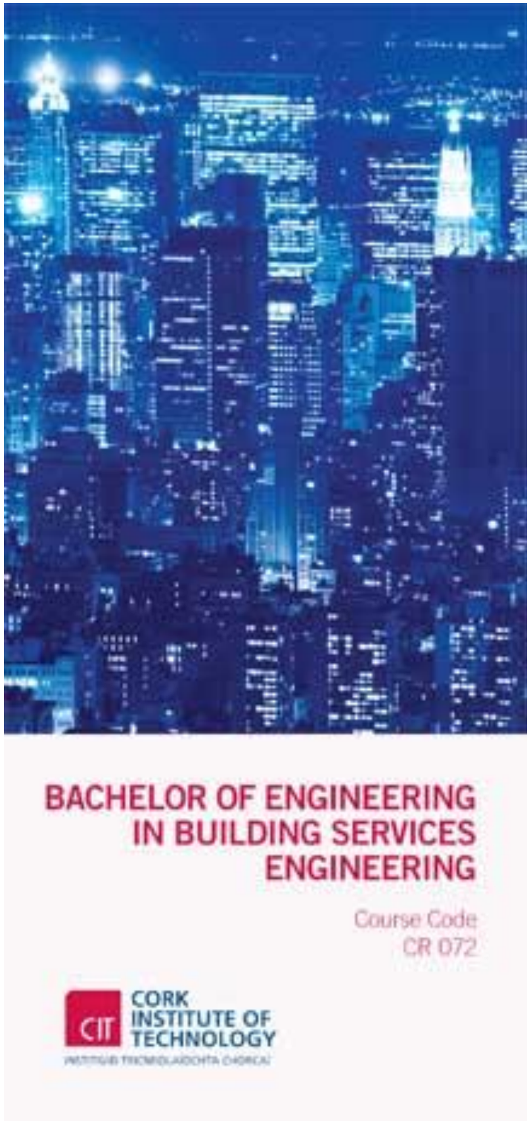
NMCI
National Maritime College of Ireland
Coláiste Náisiúnta Mara na hÉireann

Poor environmental performance of the 1974 building



Building Services and Architectural courses in CIT

Architecture factory CIT



DIRECTIVE 2010/31/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 19 May 2010

on the energy performance of buildings

(recast)

Impending legislation for NZEB

REPORT ON THE DEVELOPMENT OF COST OPTIMAL CALCULATIONS AND GAP ANALYSIS FOR BUILDINGS IN IRELAND UNDER DIRECTIVE 2010/31/EU ON THE ENERGY PERFORMANCE OF BUILDINGS (RECAST)

Section 2 –Non Residential

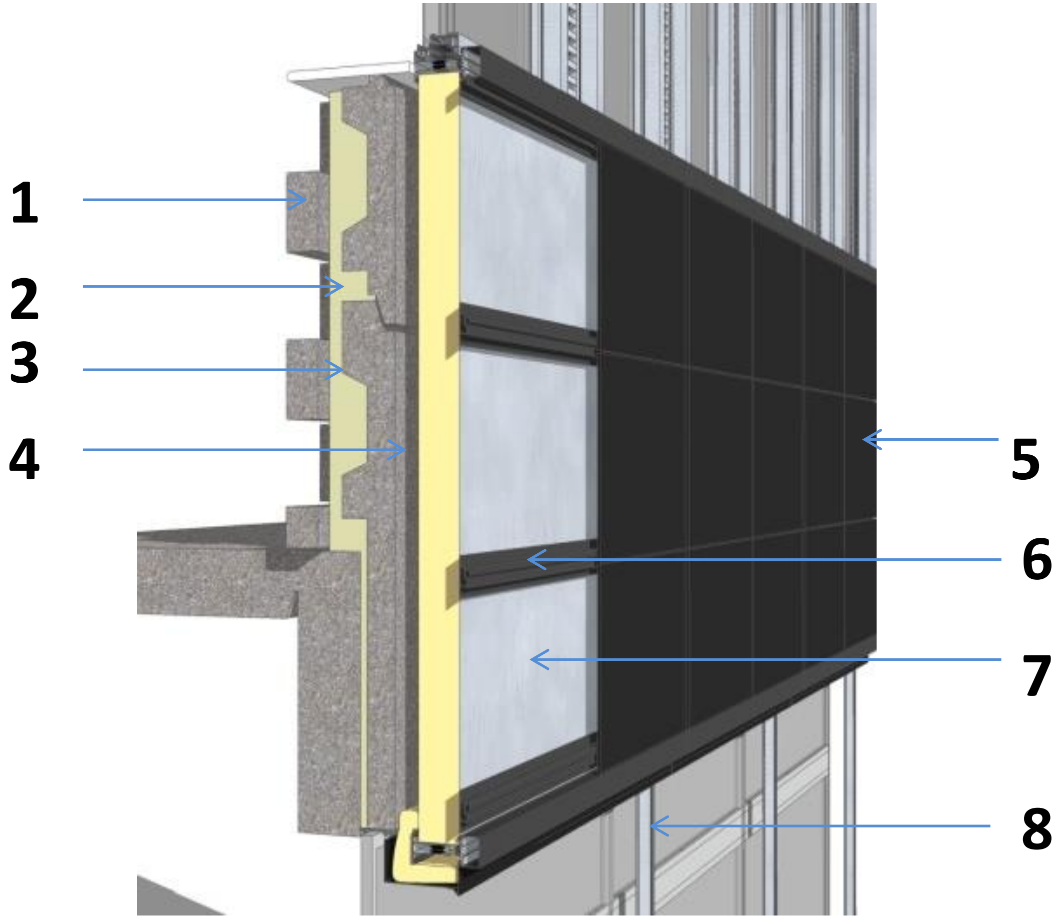
IRELAND

MARCH 2013

nZero.2020 / Specification

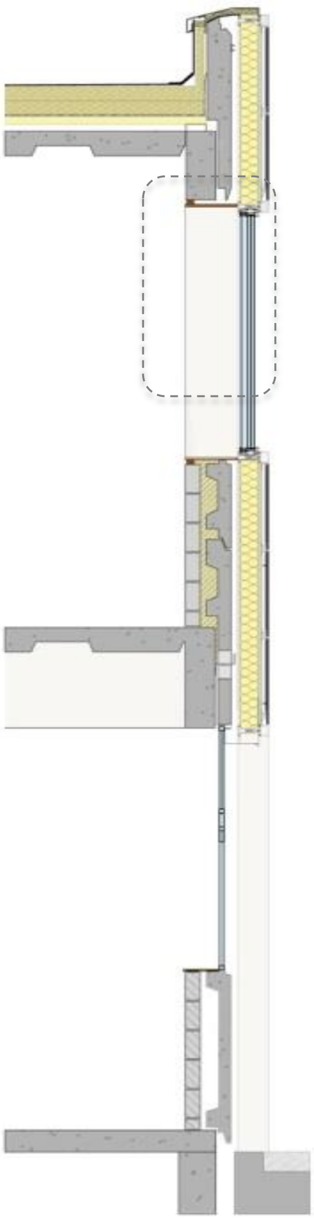
nZero.2020 / Project Build Specification

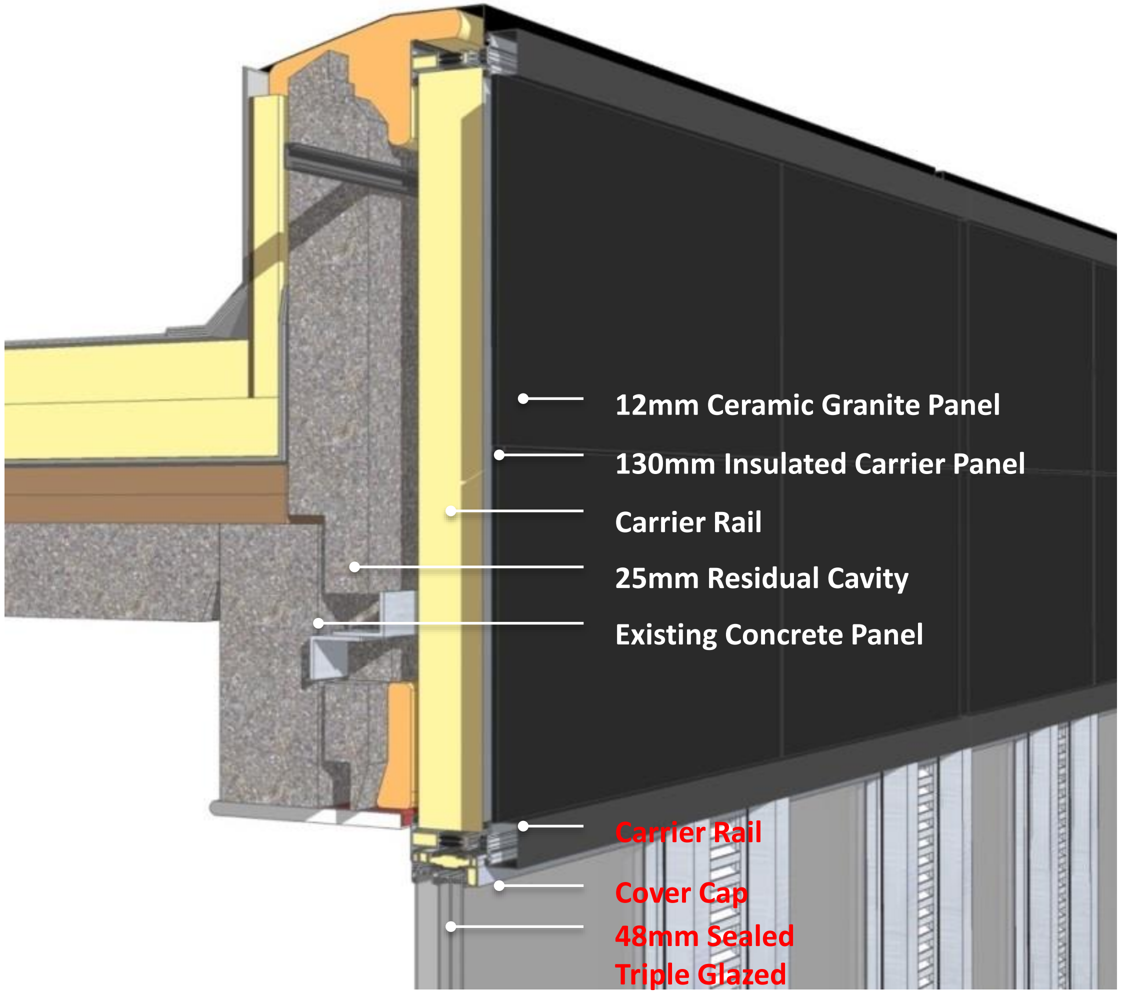
Project requirements	Solution
Low energy	ASHP connected to radiators, quadruple glazing, interstitial blinds, improved air tightness, heavily insulated
Naturally ventilated	High and low level insulated louvres (Manual & BMS control)
Minimise disruption to existing structure	New envelope wrapped around the existing building
Cannot dislocate staff/students	Flat pack off site build
Live test bed	Heavily instrumented



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

nZero.2020 / Project Build – Roof Detail





Fully integrated factory assembled module

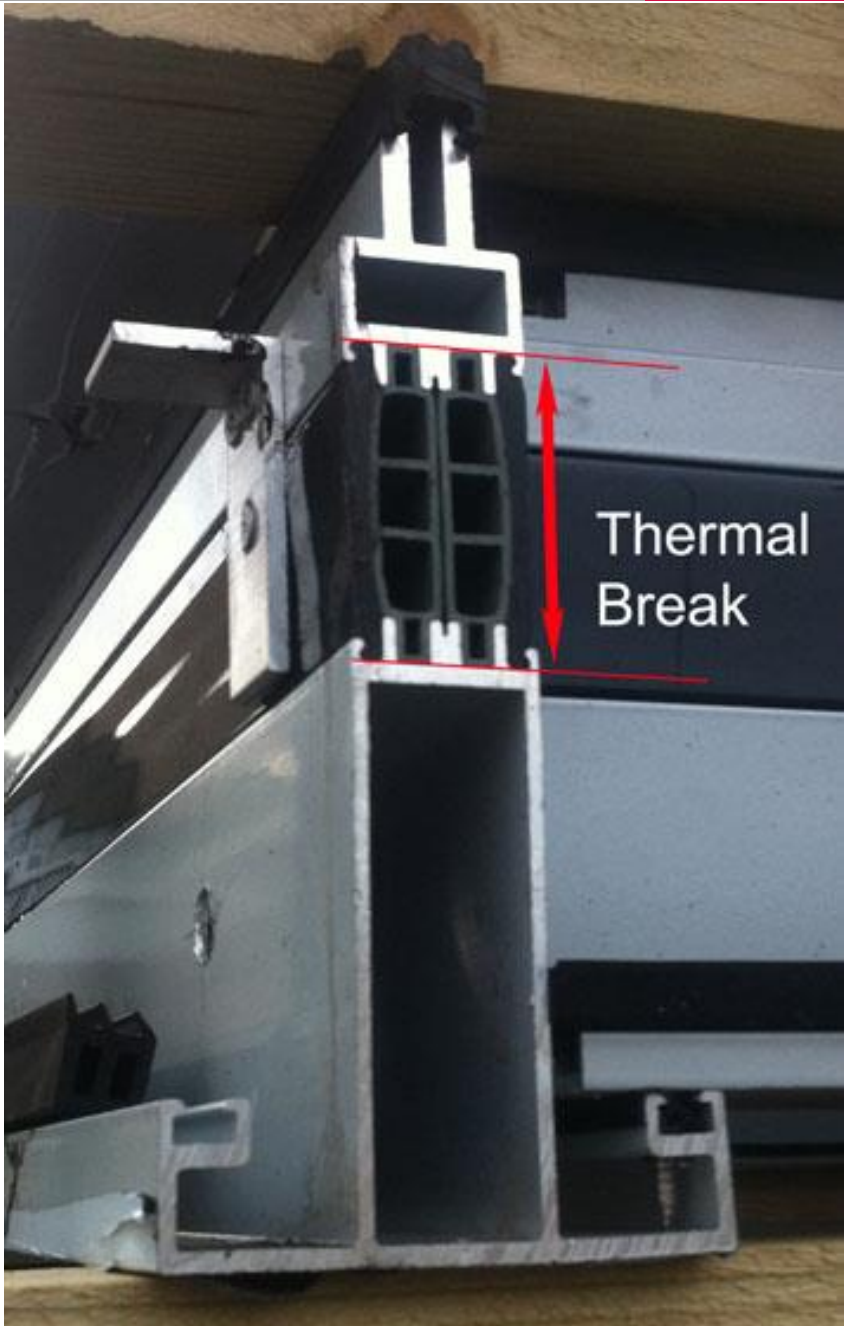
Quadruple glazed unit c/w sealed triple glazed Argon filled system/ manual interstitial blinds / inner clear float pane

Integrated insulated ventilation doors low level occupancy controlled & high level BMS automated

- Free-running indoor temperature as no HVAC system is used
- 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 $(m^3/hr)/m^2$

nZero.2020 / Project Build Ventilation Module

manual & automated purpose provided
ventilation openings with insulated doors


Thermal
Break

nZero.2020 / Project Build

nZero.2020 / Project Build

nZero.2020 / Project Build

nZero.2020 / Project Build

nZero.2020 / Project Build

nZero.2020 / Project Motivation

nZero.2020 / Testbed features

20kWp PV Installation with 1kW wind turbine and Micro Grid

nZero.2020 / testbed features

20kW dimplex dual compressor air source heat pump

nZero.2020 / testbed features

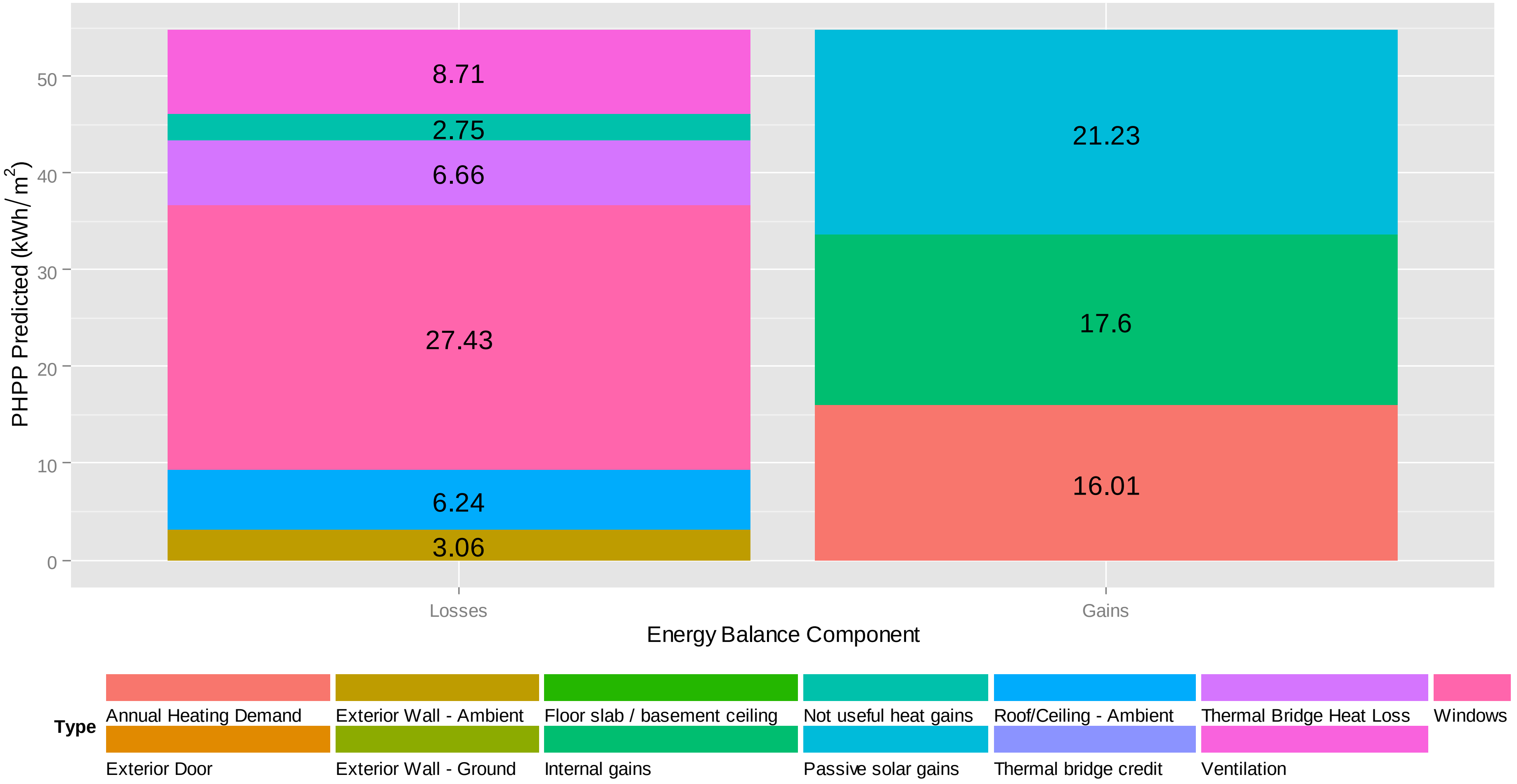
wireless Hanwell radio frequency based data logging system

nZero.2020 / Energy Performance

How does the zero2020 retrofit solution compare with the existing building on an equivalence basis?

Building	Heating (kWh/m²/yr)	Lighting (kWh/m²/yr)	Auxiliary (kWh/m²/yr)	Hot Water (kWh/m²/yr)	Total (kWh/m²/yr)
1974	386.83	46.43	3.24	16.4	452.57
Zero2020	14.25	45.47	1.91	2.51	64.14

A PHPP model has been developed to investigate how the various losses & gains contribute to the reduction in heating demand



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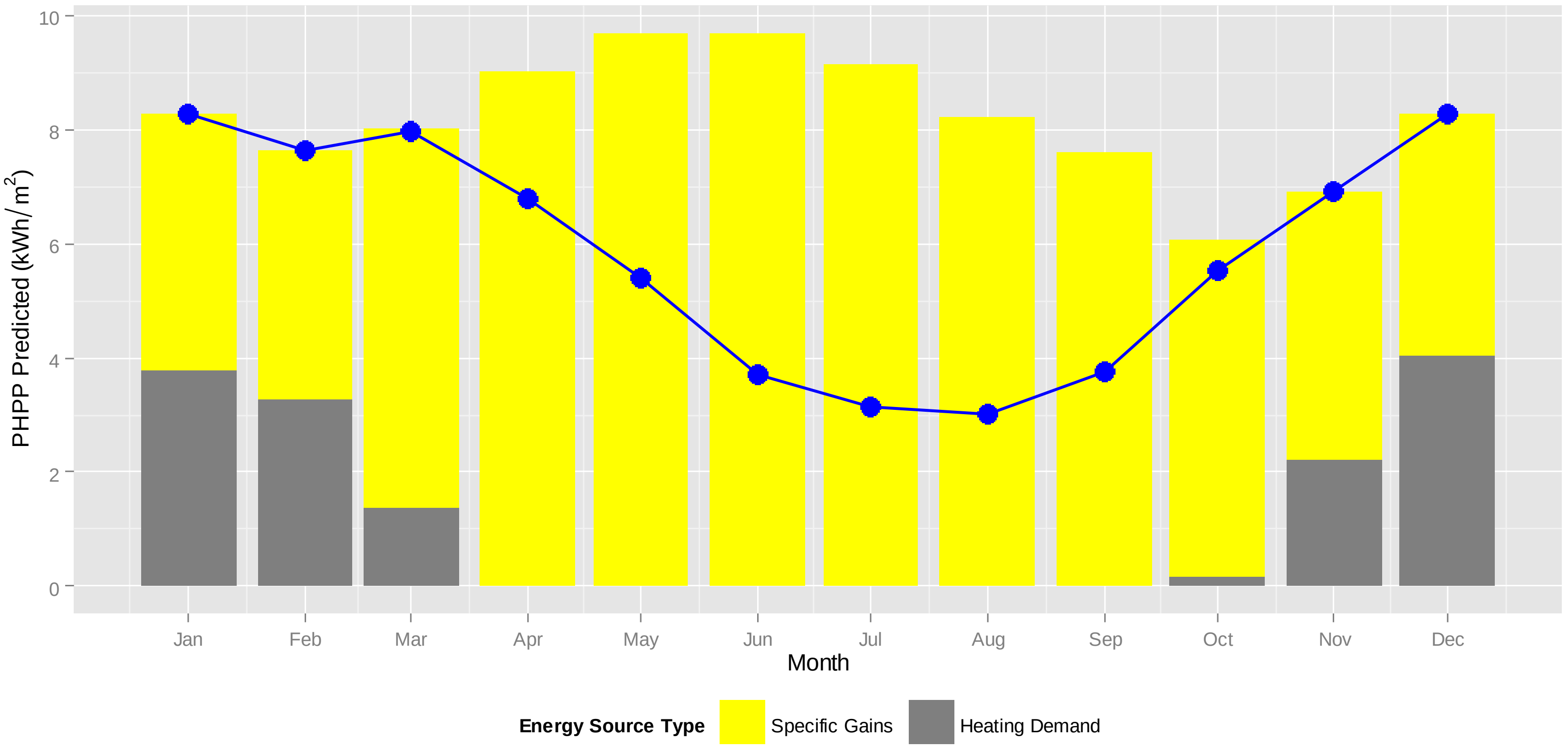
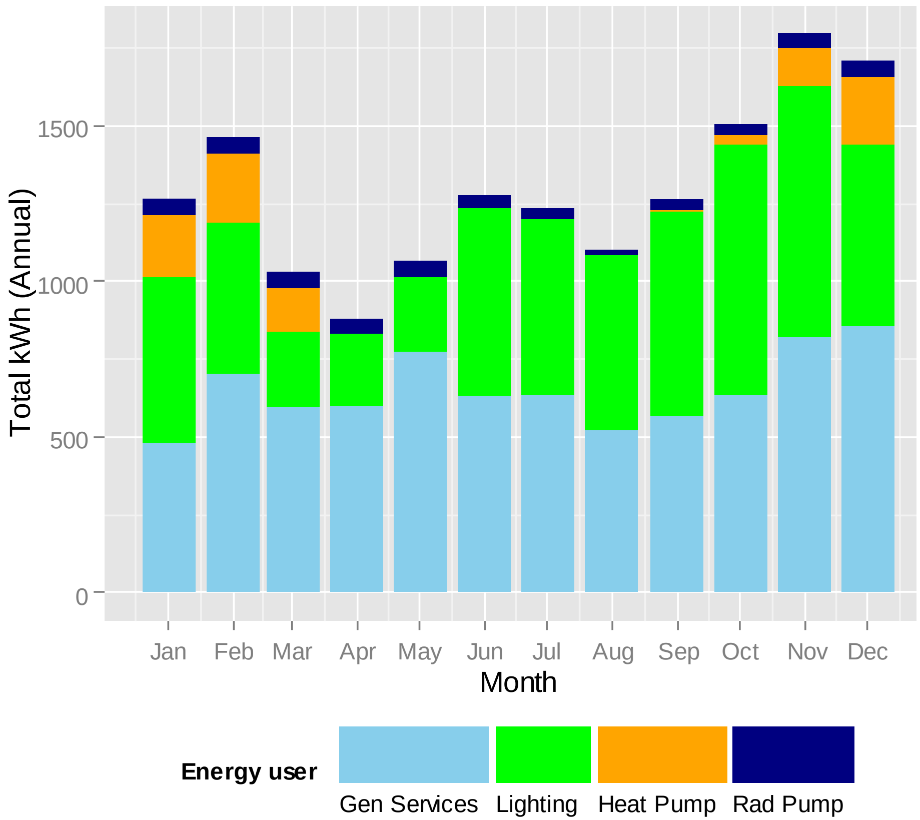
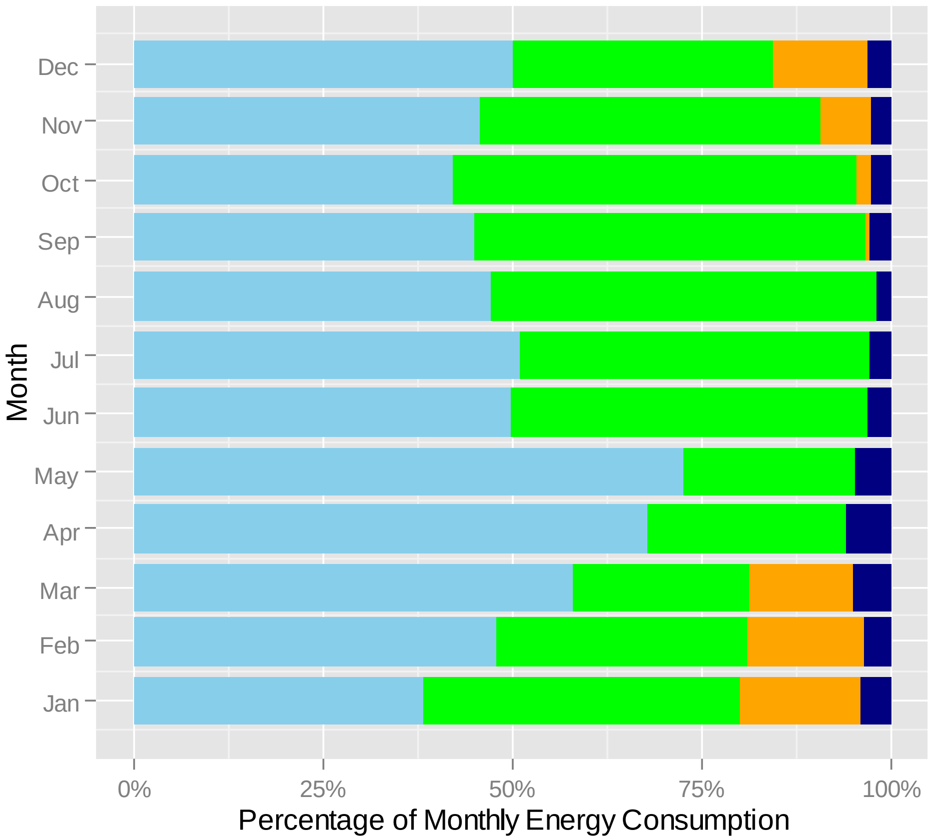
PHPP model shows a high solar gain contribution throughout the extended cooling season



2013 Monthly Totalised Energy Consumption per end use





nZero.2020 / PHPP Prediction Performance

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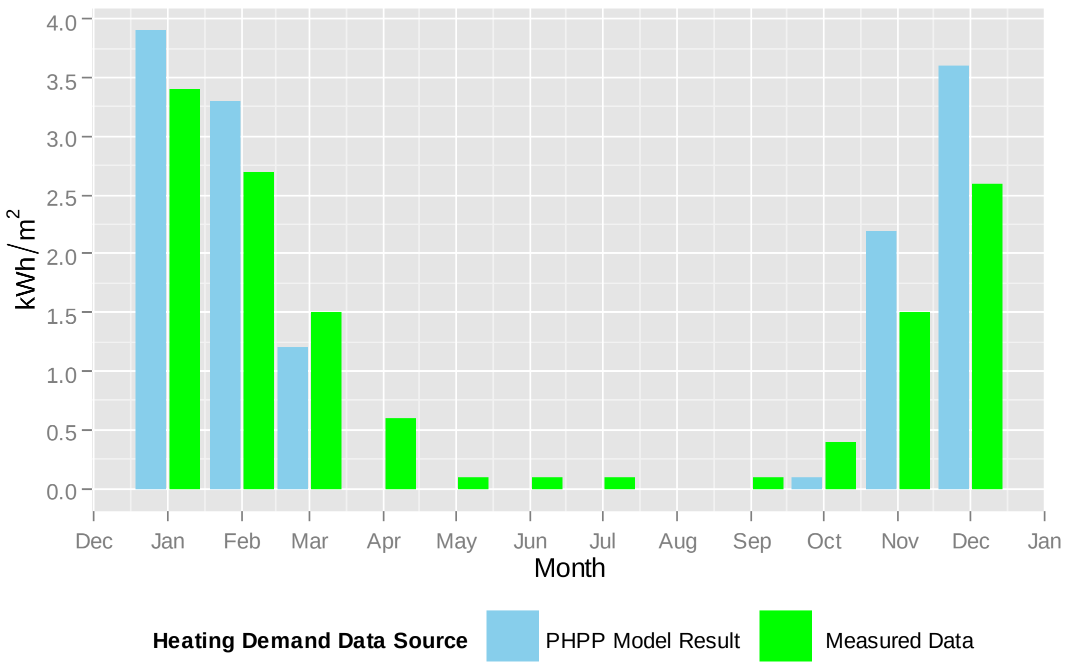
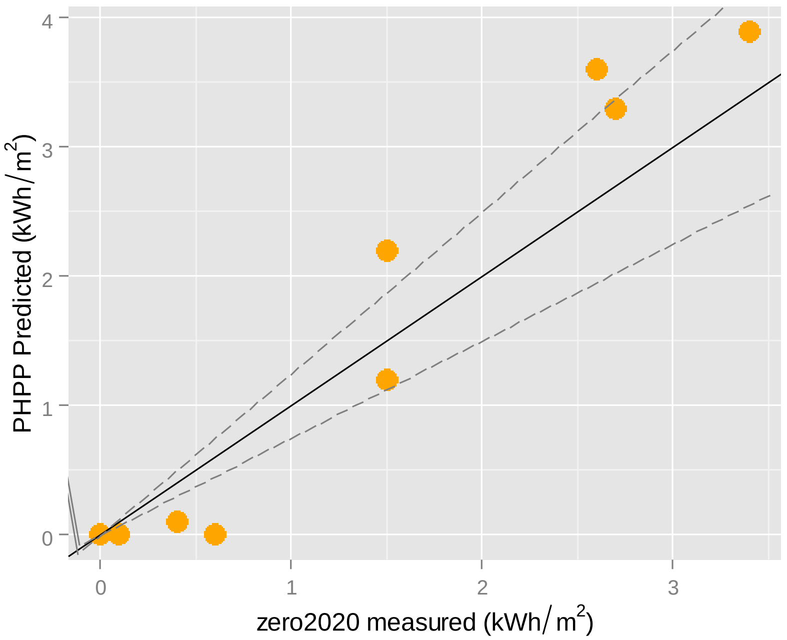
2013 Monthly Totalised Energy Consumption per end use





nZero.2020 / PHPP Prediction Performance

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2013 z2020 Delivered Heating Energy = 13.3 kWh/m² annual

2013 PHPP Delivered Heating Energy = 14.7 kWh/m² annual

Specific building demands with reference to the treated floor area — use: Monthly method

		Value	Unit	Requirements	Fulfilled?*
	Treated floor area	222.5	m^2		
Space heating	Annual heating demand	**14**	**kWh/(m²a)**	25 kWh/(m²a)	**yes**
	Heating load	**25**	**W/m²**	-	**-**
Space cooling	Overall specific space cooling demand		**kWh/(m²a)**	-	**-**
	Cooling load		**W/m²**	-	**-**
	Frequency of overheating (> 25 °C)	0.0	%	-	**-**
Primary Energy	Space heating and cooling, dehumidification, household electricity.		**kWh/(m²a)**	120 kWh/(m²a)	
	DHW, space heating and auxiliary electricity		kWh/(m²a)	-	**-**
	Specific primary energy reduction through solar electricity	0	kWh/(m²a)	-	**-**
Airtightness	Pressurization test result n_{50}	**1.6**	**1/h**	1 1/h	**no**

* empty field: data missing; '-': no requirement

nZero.2020 / Ventilation Rates

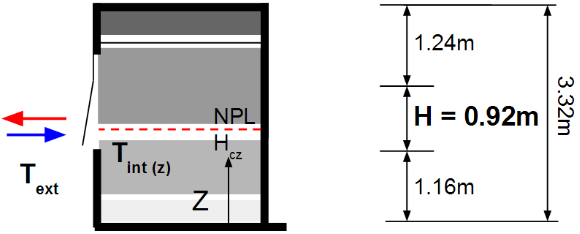
Manual & Automated Ventilation Configurations

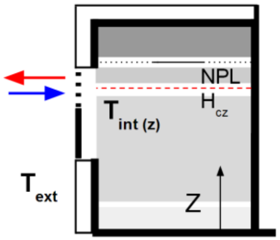
CS.01

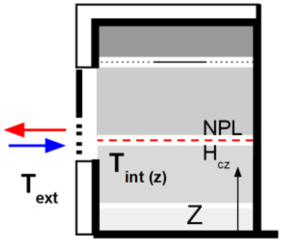
RS.02

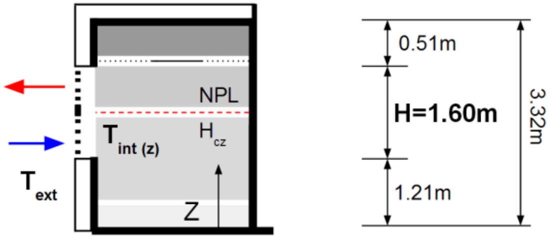
RS.03

RS.04









nZero.2020 / Wind & Buoyancy Driven Ventilation

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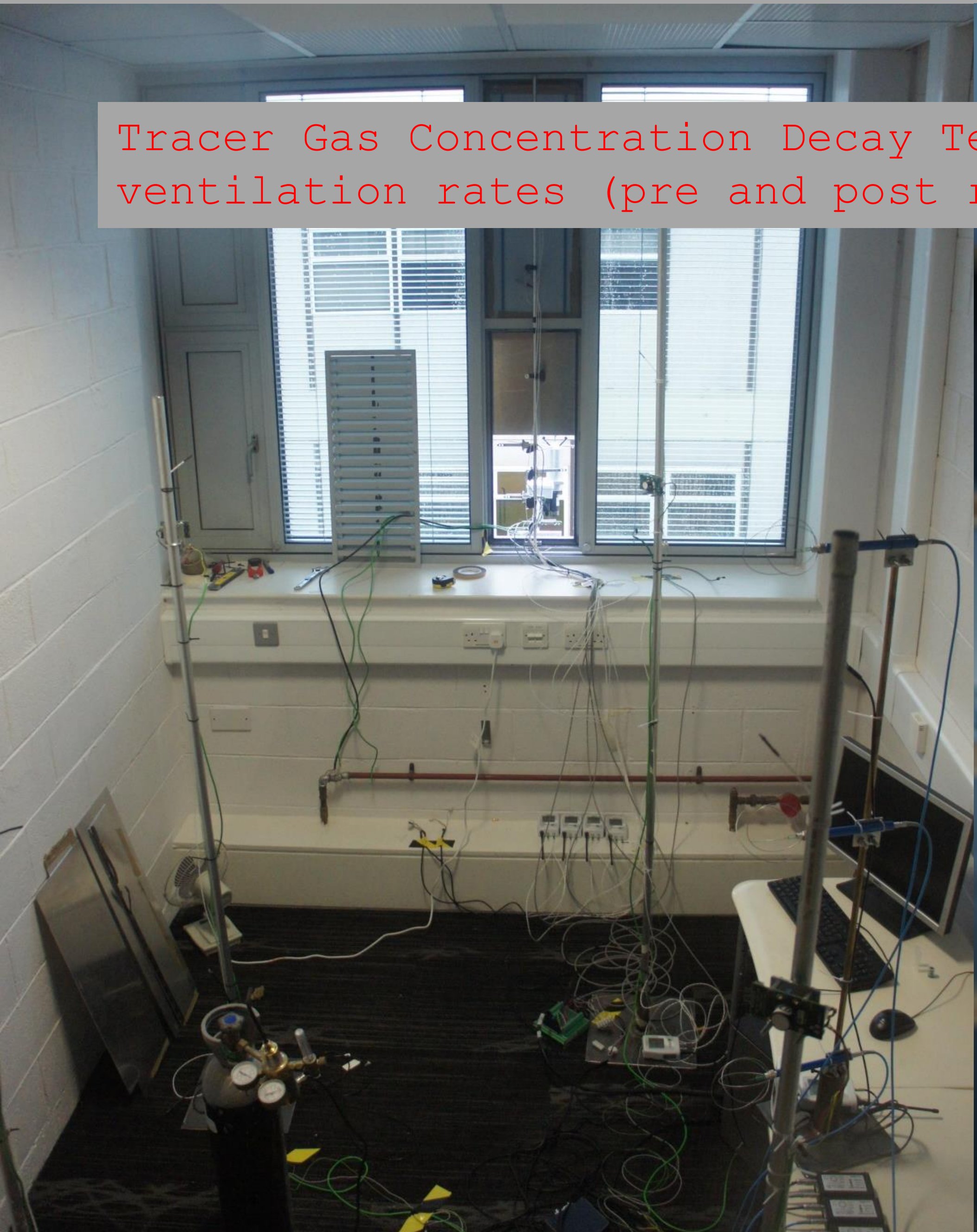
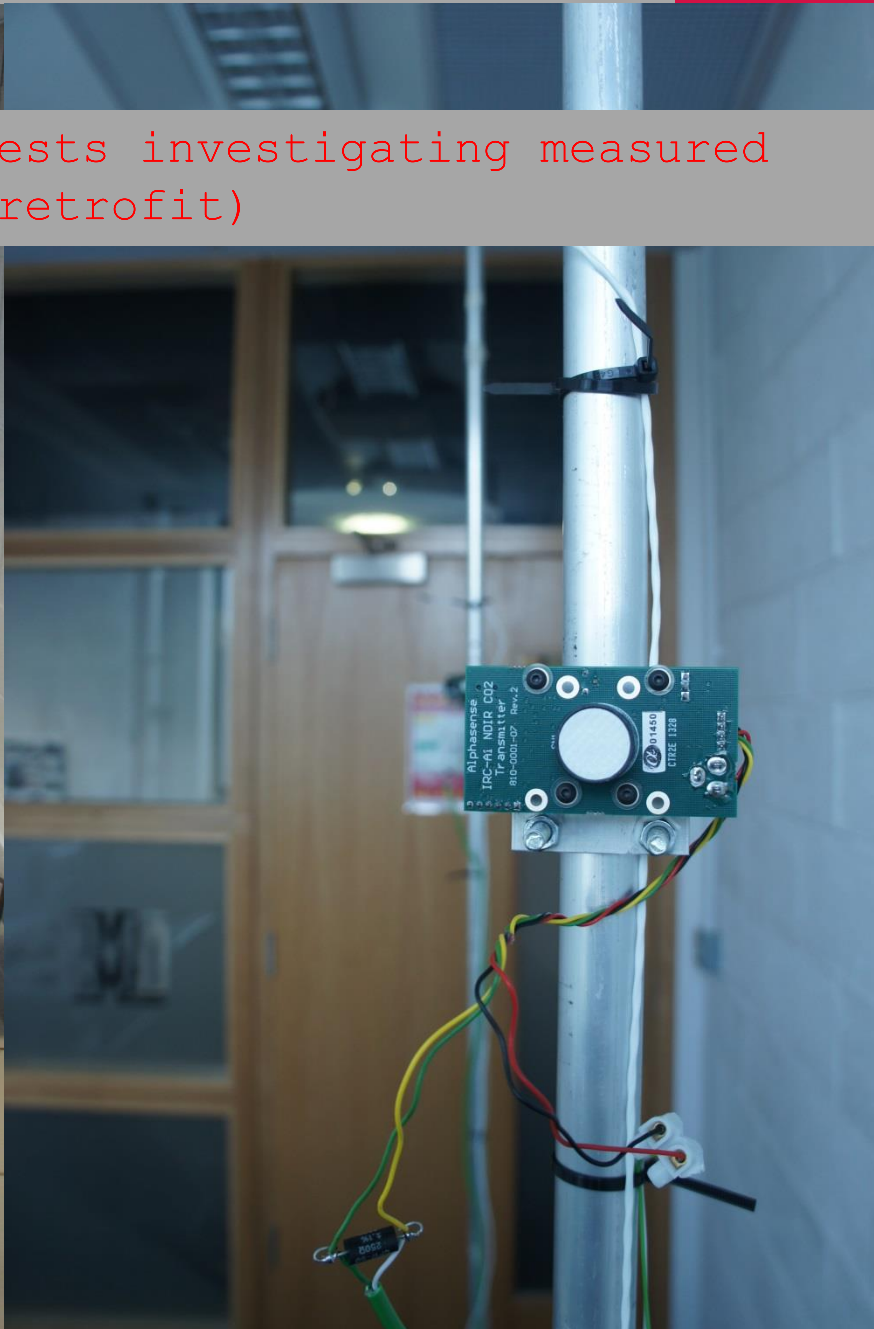
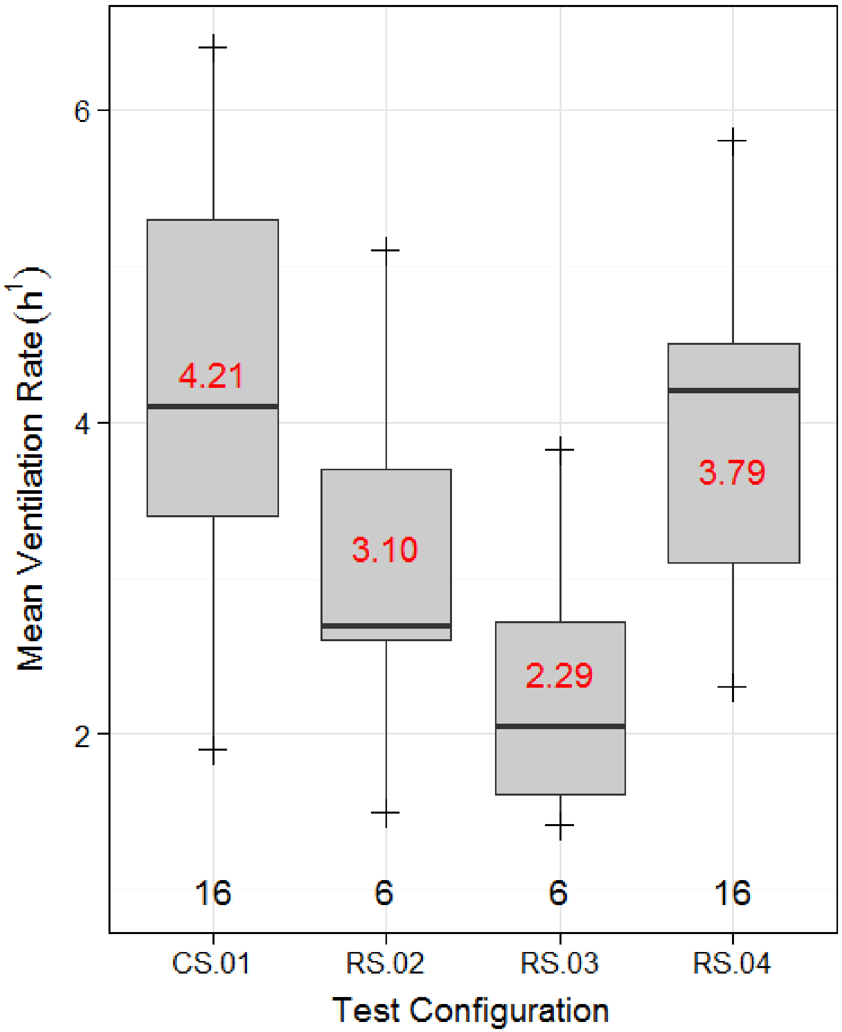
Tracer Gas Concentration Decay Tests investigating measured ventilation rates (pre and post retrofit)





Boxplot distributions of Single Sided ventilation ACH according to configurations



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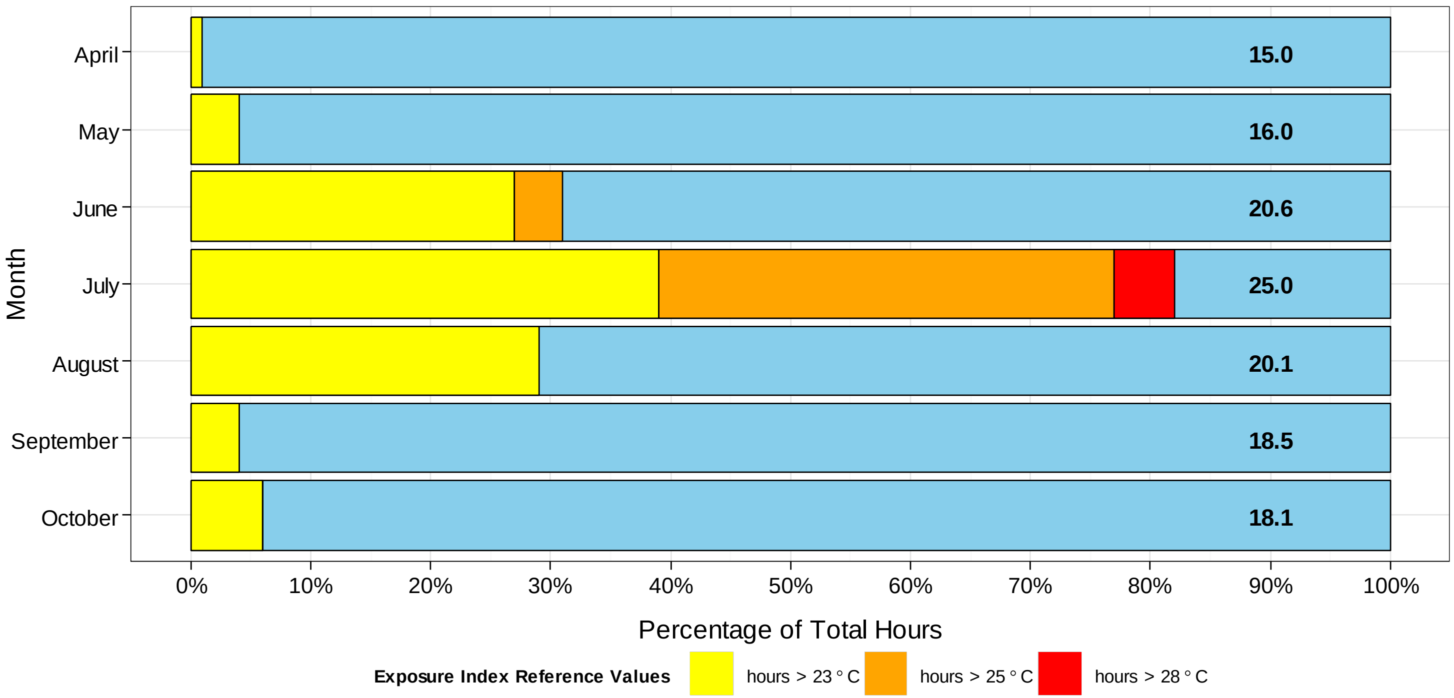
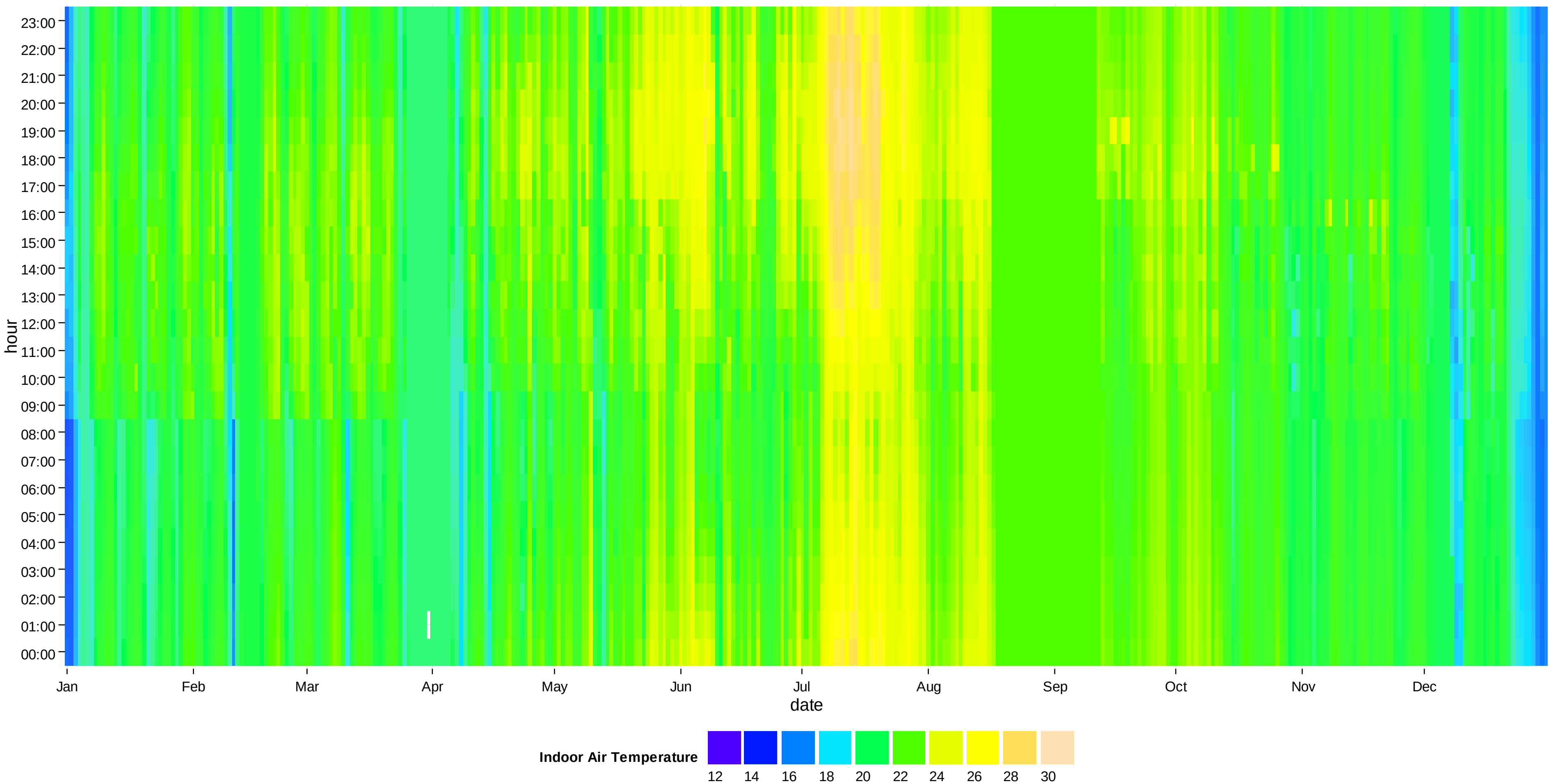
nZero.2020 / Overheating Risk

% of Total Monthly Hours for Indoor Air Temperature 2013

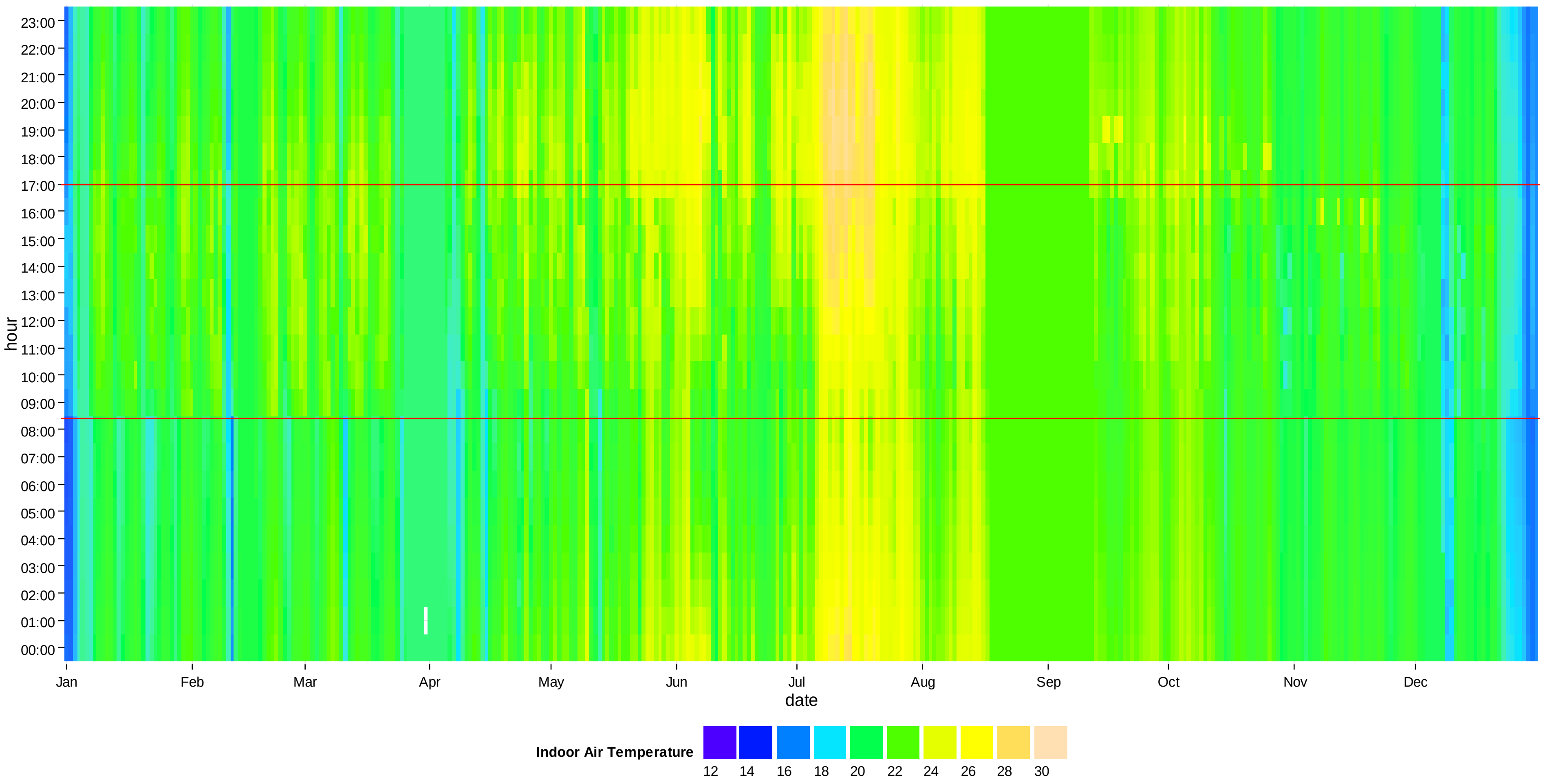


Heat map Open Plan office 2013



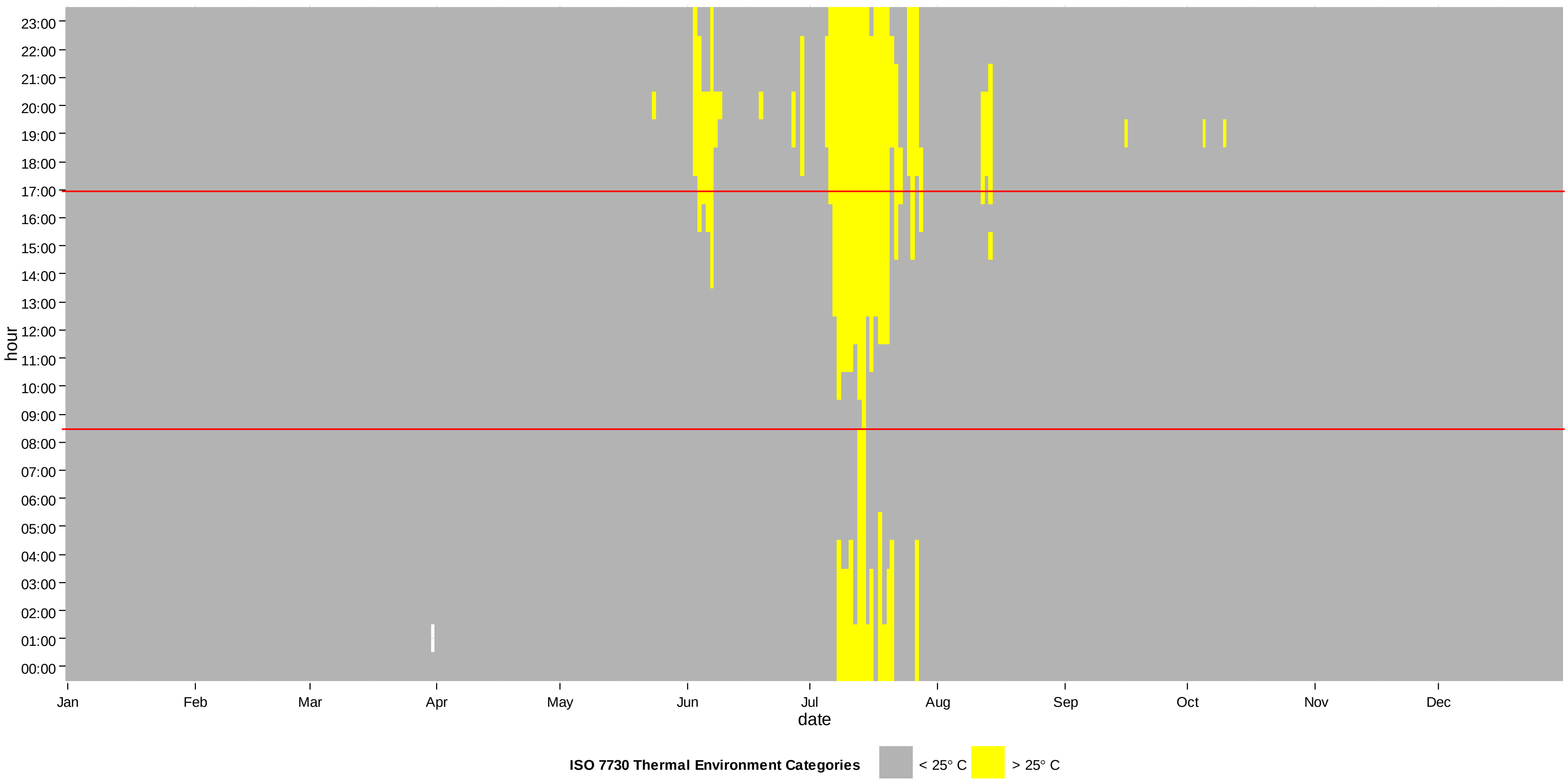
nZero.2020 / Indoor environment

Heat map Open Plan office 2013

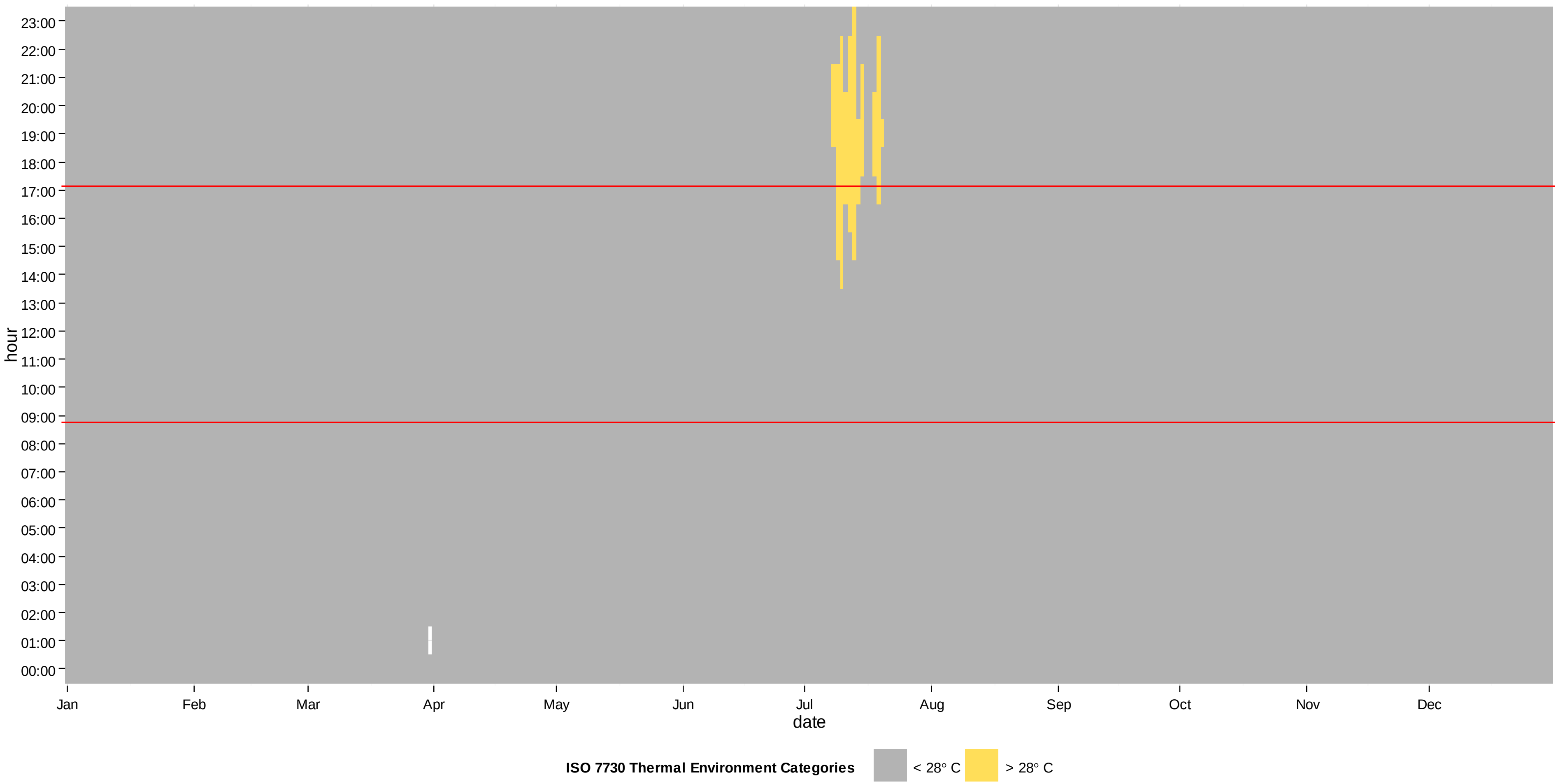


nZero.2020 / Indoor environment

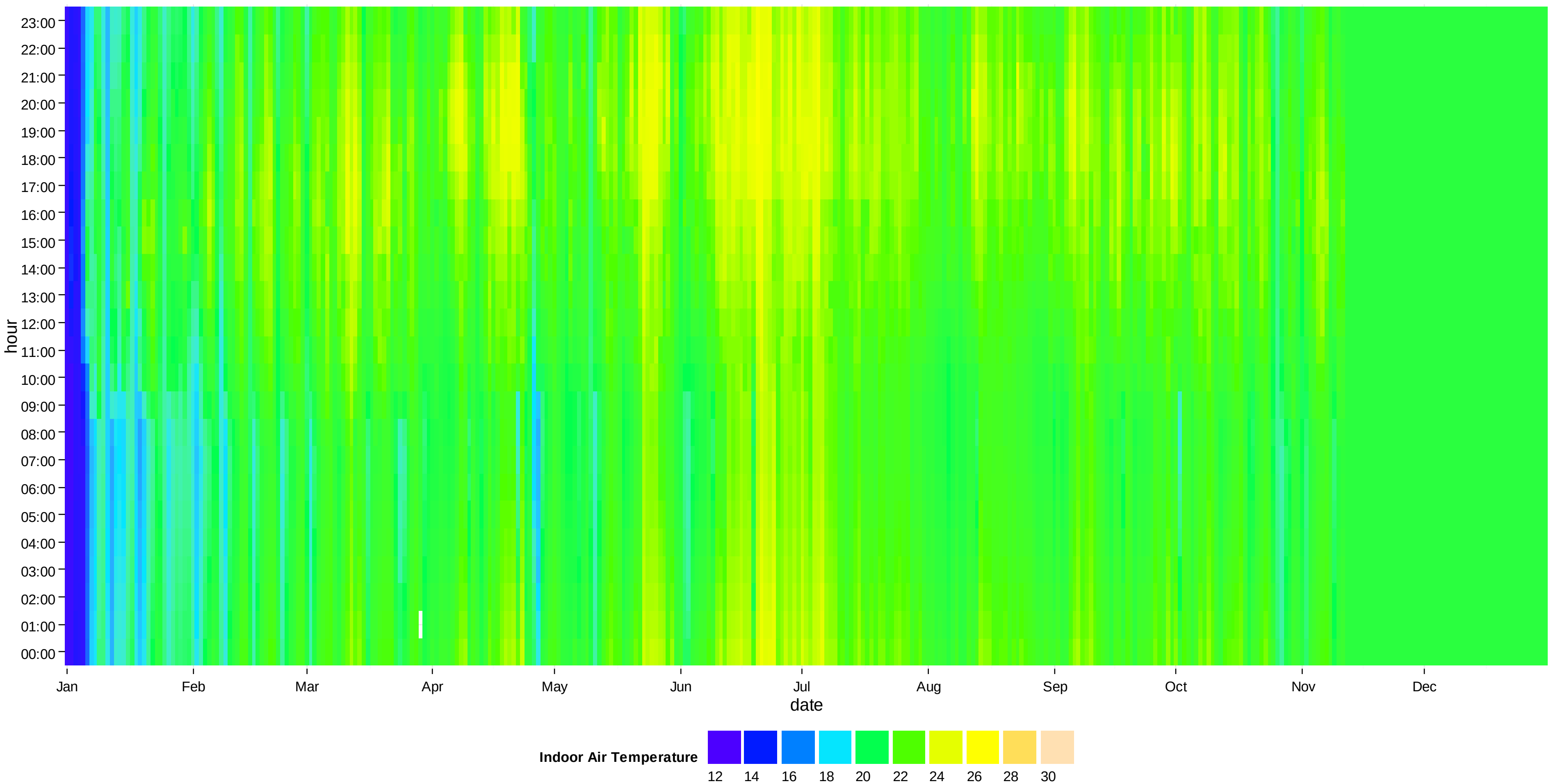
Heat map > 25°C Open Plan office 2013



Heat map > 28°C Open Plan office 2013

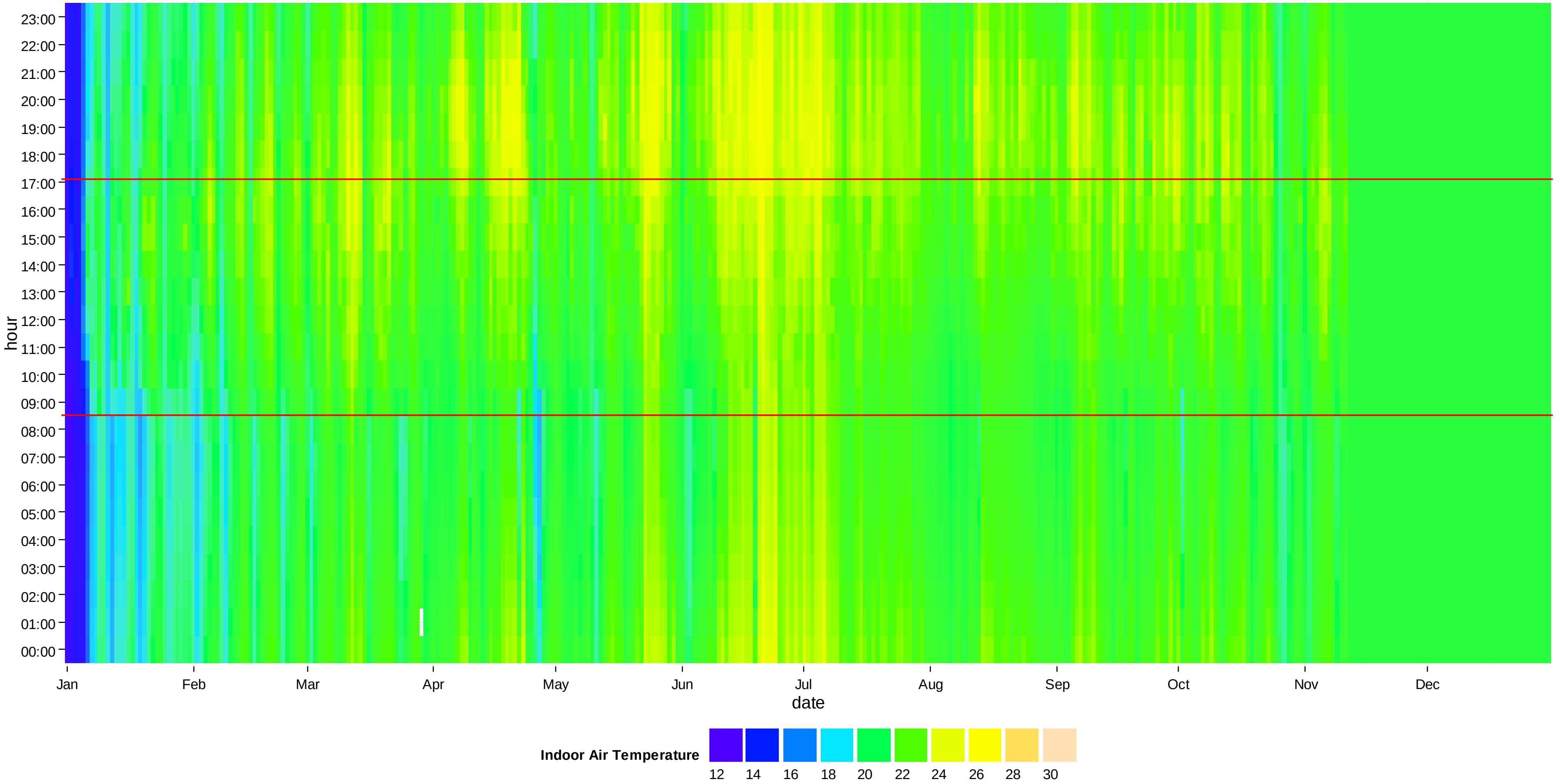


Heat map Open Plan office 2015

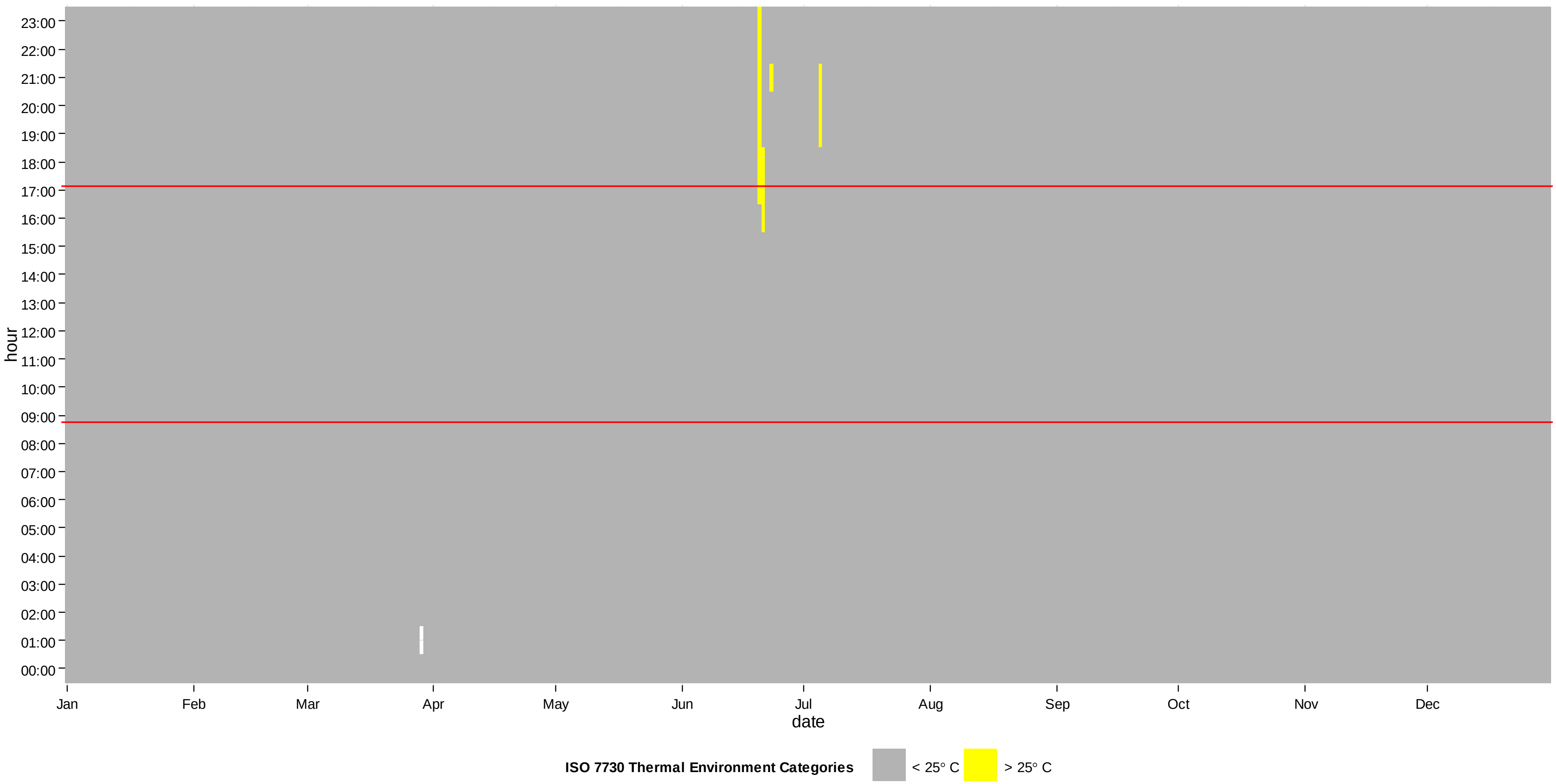


nZero.2020 / Indoor environment

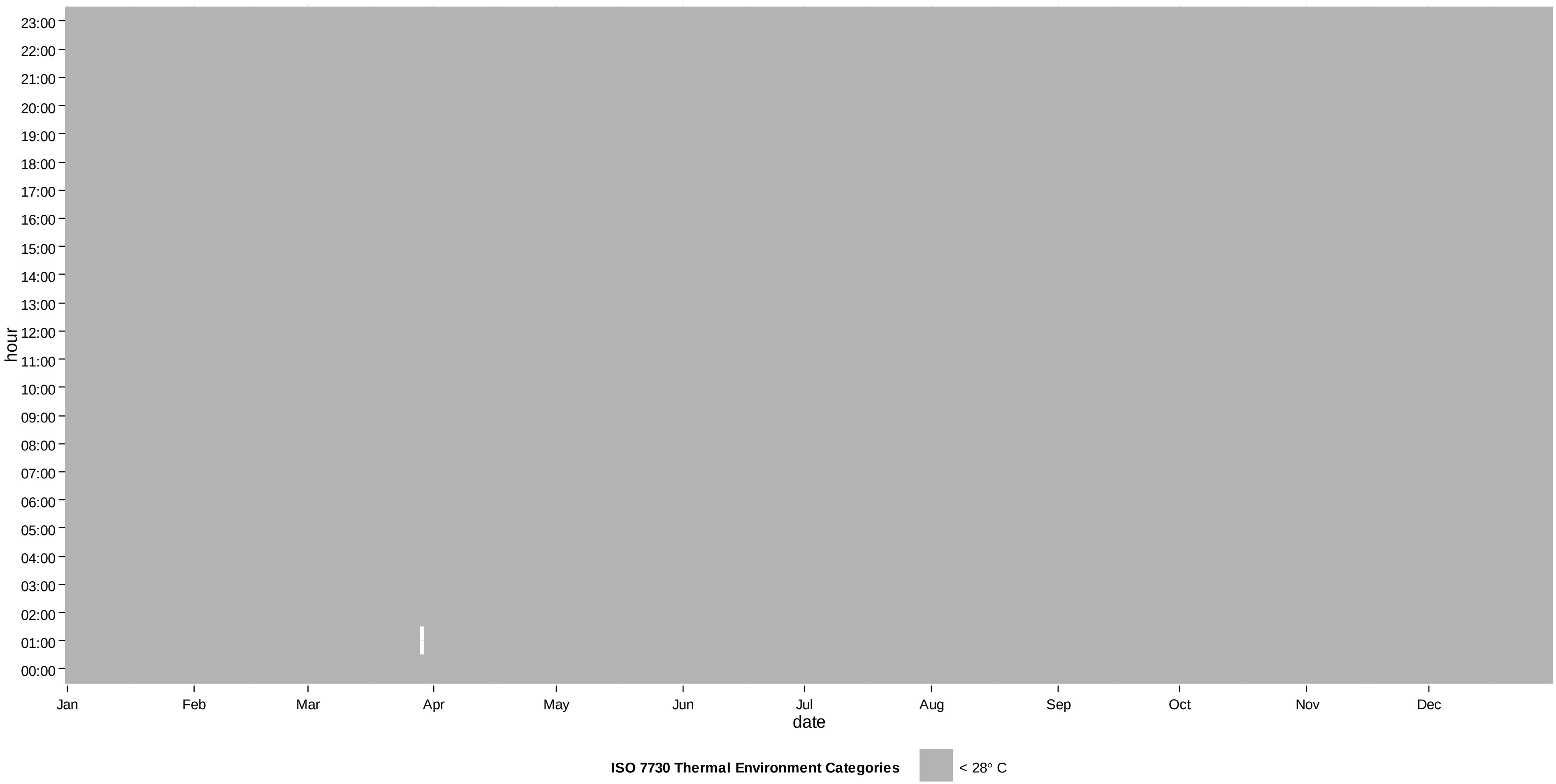
Heat map Open Plan office 2015



Heat map > 25°C Open Plan office 2015



Heat map > 28°C Open Plan office 2015



Summary Open Plan (All hours) office 2013

2013 Total Hours

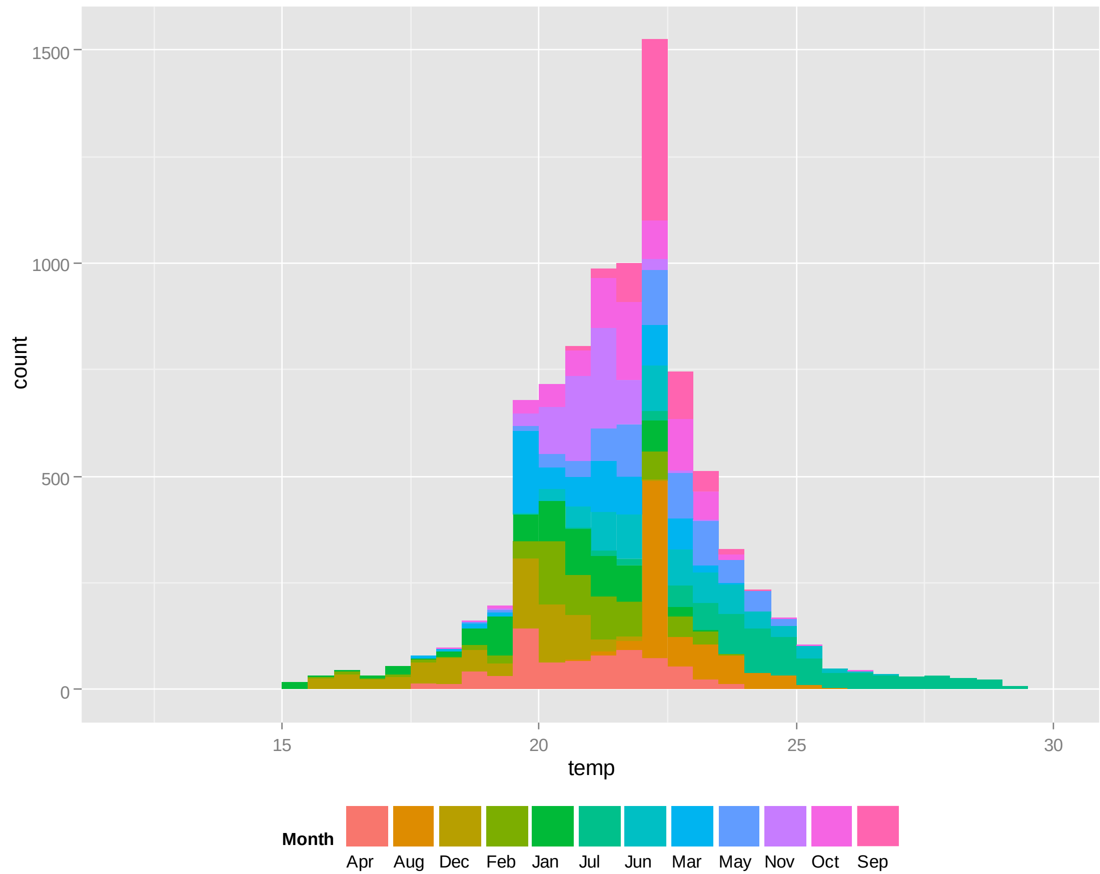
No. hrs > 25 = 3.9%

No. hrs > 28 = 0.6%

2013 Occupied Hours

No. hrs > 25 = 5.5%

No. hrs > 28 = 0.72%



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Summary Open Plan (All hours) office 2013 & 2015

2015 Total Hours

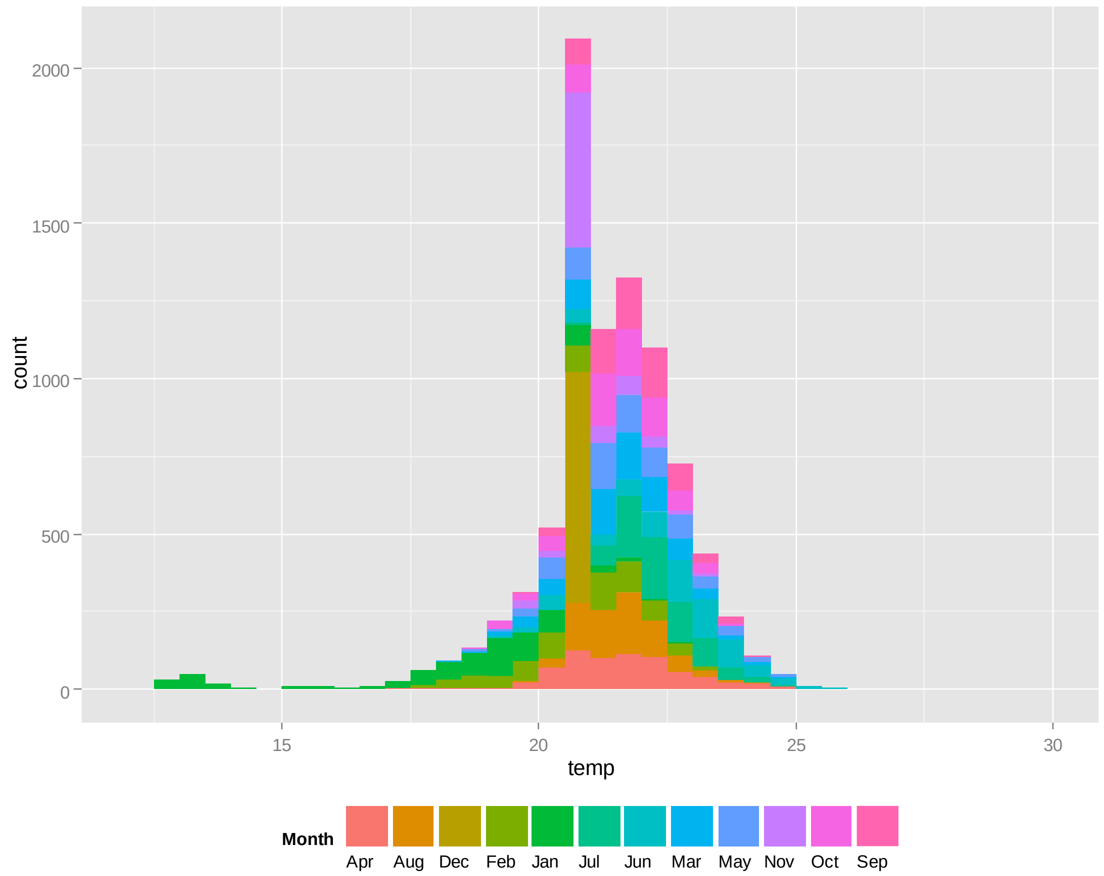
No. hrs > 25 = 0.15%

No. hrs > 28 = 0%

2015 Occupied Hours

No. hrs > 25 = 0.034%

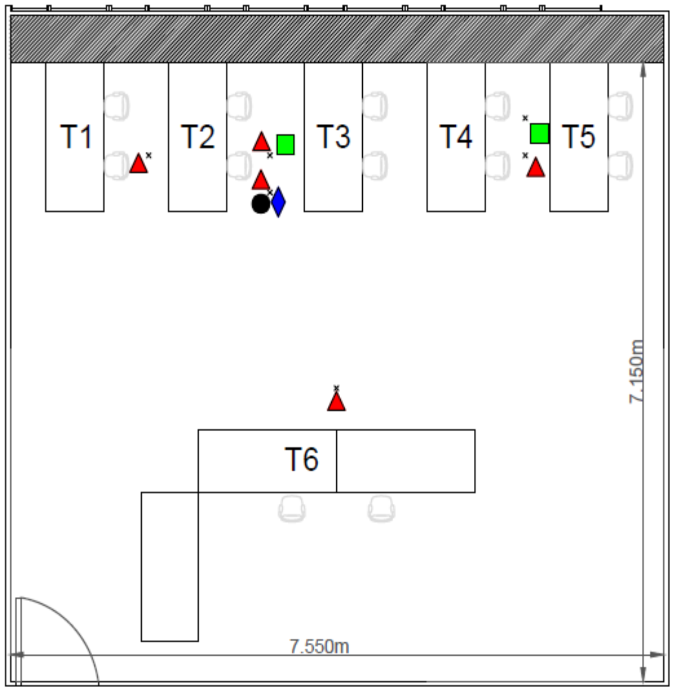
No. hrs > 28 = 0%

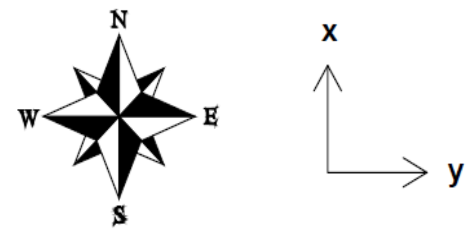


nZero.2020 / Thermal Comfort

nZero.2020 / Thermal Comfort Evaluation

Ventilative cooling performance in a simulated overheating scenario





	2 Bi-directionnal anemometers (on x and y axis)
	3 air temperature sensors (0.1m ; 0.6m ; 1.1m)
	Black globe thermometer
	Relative humidity sensor

Study set up / methodology

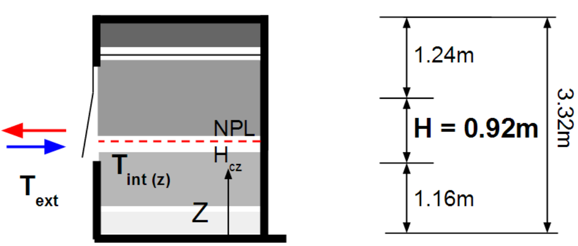
Manual & Automated Ventilation Configurations

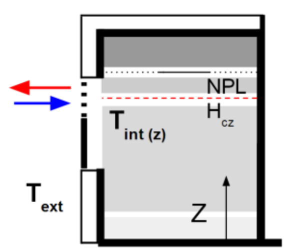
CS.01

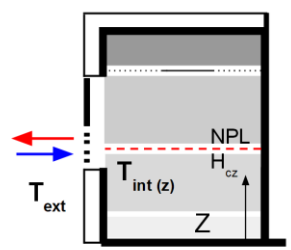
RS.02

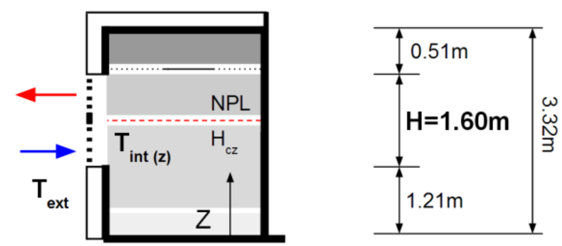
RS.03

RS.04

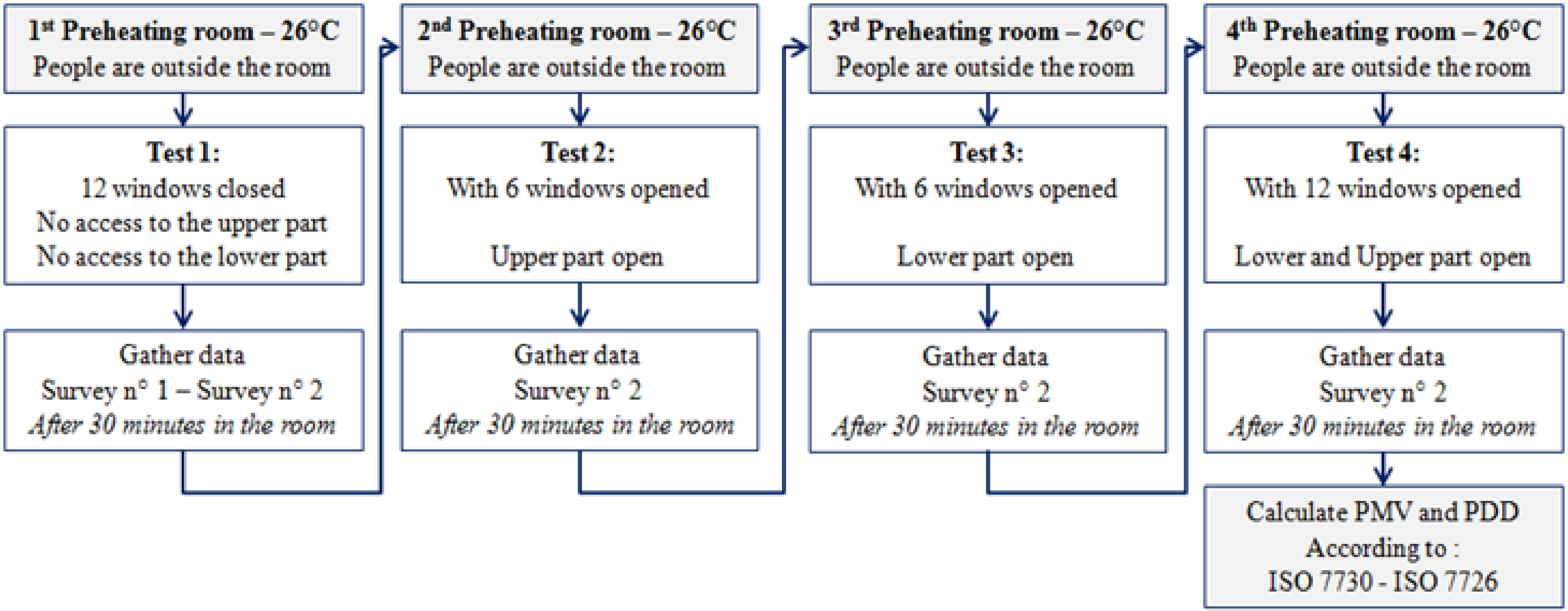








nZero.2020 / Thermal Comfort Evaluation



Study set up / methodology

nZero.2020 / Heating Energy Consumption 2014

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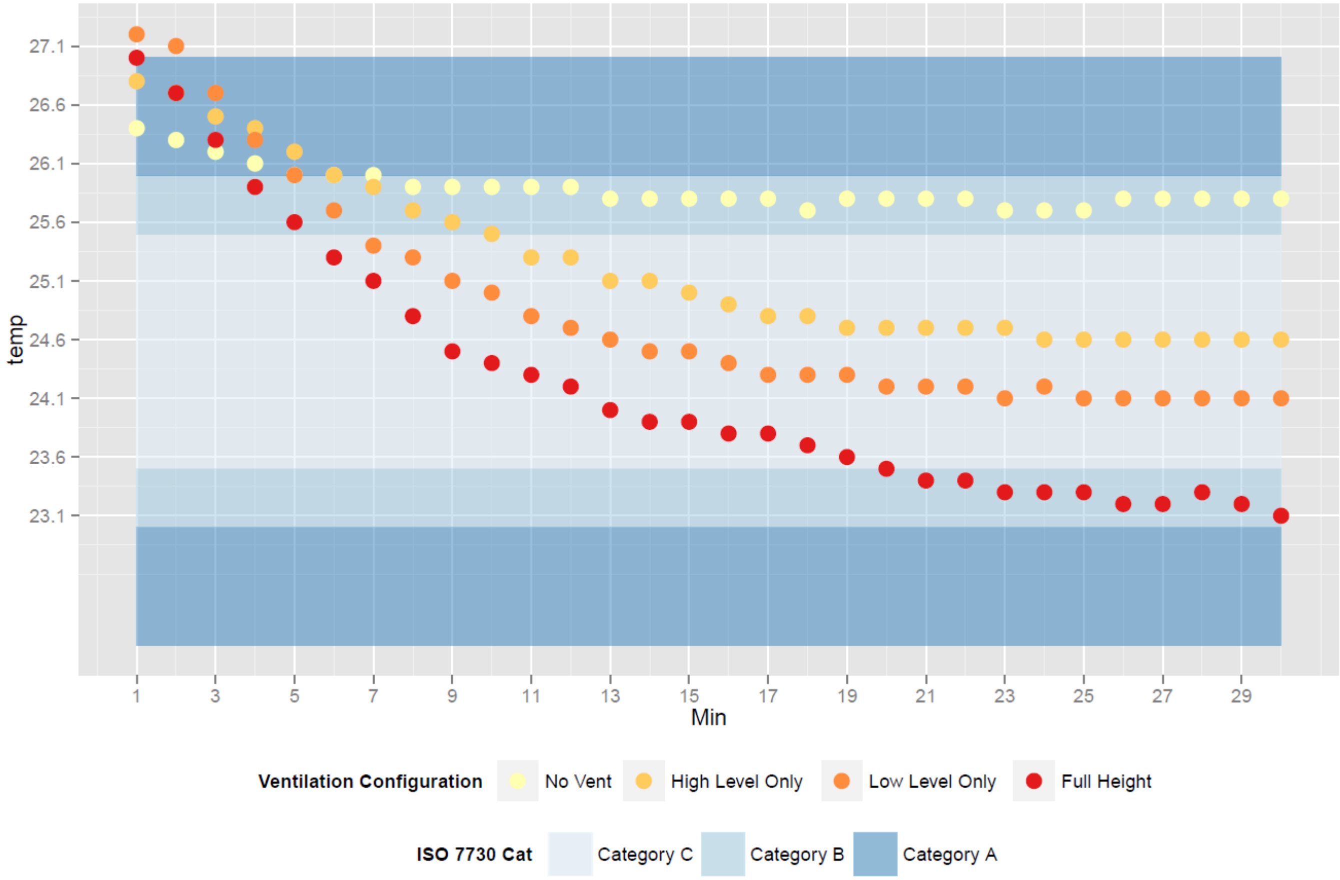
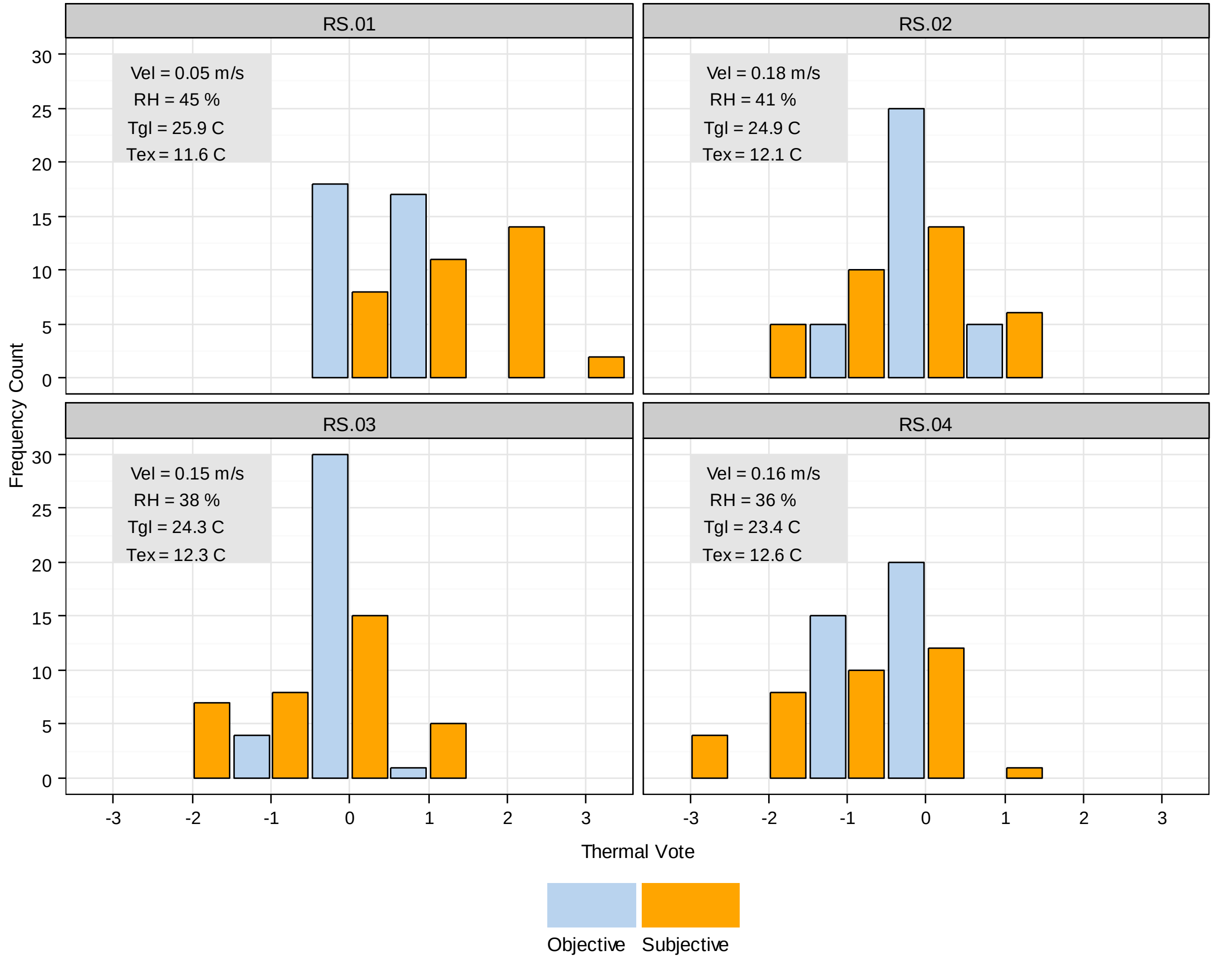
Measured indoor air temperature profiles during thermal comfort tests for each ventilation configuration



Recorded PMV from subjective survey data along with a comparison to the Fanger PMV model



What are we learning?

nZero.2020 / What are we learning

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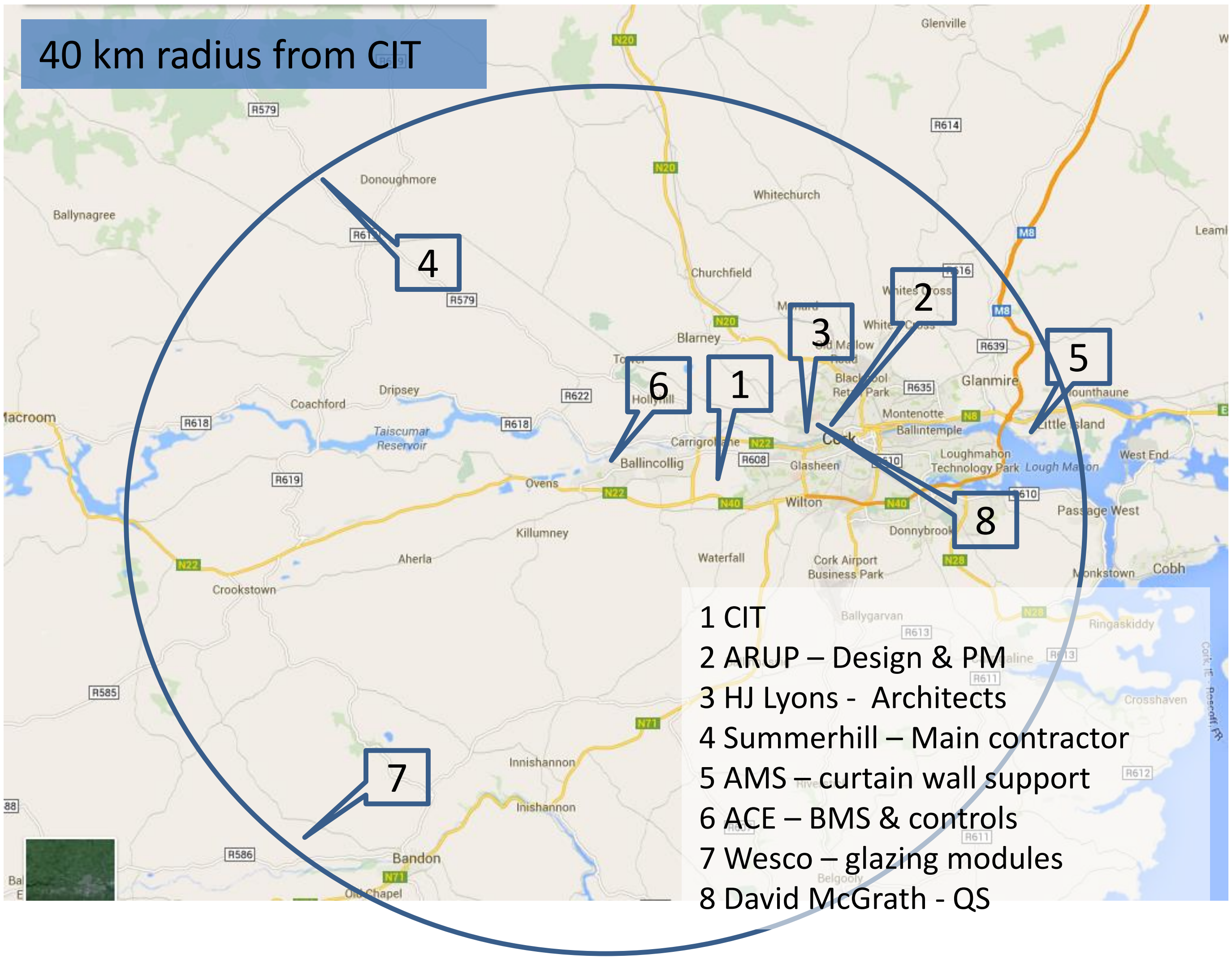
- More data showing people like natural ventilation & openable windows
- PHPP gives realistic predictions for heating energy consumption even within non residential environments
- Surprisingly, so did SBEM for annualised values
- Up to 4 ACH possible with NV SS slot louver systems
- Low energy can mean comfortable but adaptive approach important (free running buildings)
- Overheating still likely even with night cooling
- It is difficult to obtain consistent, accurate measurements over extend periods of time

- Project requirement :
  - a low energy building that could support our undergraduate in Building Energy Systems and post graduate research
- Project management
  - Building Services consultant appointed as the project designers and managers to emphasise priority on energy reduction
- Good decision ? YES

- Localisation was critical for problem solving
  - All parties involved were typically within a 40 km radius of the job
    - Design consultant and project managers, ARUP
    - Architect, HJ Lyons
    - Main contractor, Summerhill construction
    - Controls/BMS, ACE
    - QS, Dave McGrath Associates
  - The only exception was Kingspan


40 km radius from CIT
4
2
3
5
6
1
8
7
Donoughmore
Ballynagree
Whitechurch
Glenville
Churchfield
Blarney
Glanmire
Dripsey
Coachford
Ballincollig
Ovens
Killumney
Aherla
Crookstown
Waterfall
Wilton
Glasheen
Donnybrook
Passage West
Cobh
Innishannon
Bandon
1 CIT
2 ARUP – Design & PM
3 HJ Lyons - Architects
4 Summerhill – Main contractor
5 AMS – curtain wall support
6 ACE – BMS & controls
7 Wesco – glazing modules
8 David McGrath - QS

- Industry support
  - Enthusiasm from all stakeholders wrt low energy demonstration projects is vital
    - It pushes the boundaries
    - It challenges standard solutions
    - It produces very good build quality
    - Pride in a finished product is a great selling point

- Occupant behaviour
  - Natural ventilation under user control will only work with occupant buy-in to the concept
  - Lighting control under user control will only work with occupant buy-in to the concept
  - Motivation for users wears off with time (can be a very short time in some cases!!!!)
  - Positive re-enforcement can have a negative effect! (how do you keep focus on energy reduction before the user gets fed up with reminders?)

- Low carbon low energy is not the primary goal
  - The building must be fit for purpose
  - A low carbon, low energy building with poor user satisfaction is a failure
  - Design around the person first

- Claims of low carbon, low energy, good thermal environment etc are no good without the data to back them up
  - Meter as much as possible
  - Monitor internal environmental conditions in as many places as possible
  - If it is a refurbishment project can you get in and monitor for a significant period pre-refurbishment in order to establish a baseline

- Warning about monitoring!!!
  - Data needs to be analysed, interpreted and reported
  - This needs to be done for a few years post occupancy
  - If you can’t finance this resource then there is no point in data-logging!

nZero.2020 / **Thank you for listening**