IEA EBC Annex 62 - Ventilative Cooling

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SEAI IEA-EBC Research Seminar 13th Nov 2013

Agenda

- Climate Cooling Potential
- Annex 62 background, objectives, organisation
- CIT planned contribution to Annex 62
- CIT Zero2020 – A low energy retrofit Annex 62 case study
- Current work supporting Annex 62 objectives
- Planned work supporting Annex 62 objectives

Climate Cooling Potential

- Nearly-zero energy buildings have lead to an increased need for cooling – not only in summer but all year.
- Elevated temperature levels are the most reported problem in post occupancy studies - even in the "heating season"
- Cooling requirements in low energy buildings designed around heating energy reduction principles in cold climates are being underestimated with simplified tools
- Utilization of the cooling potential of outdoor air can be an attractive and energy efficient solution
- Cooling is correlated with solar and internal heat load and not outdoor temperature

Related Annexes

- Annex 27 – domestic ventilation systems (air quality)
- Annex 28 – low energy cooling system
- Annex 35 – hybvent
- Annex 44 – building construction elements

Climate Cooling Potential

AAU work on Climatic potential of untreated outdoor air

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Climatic potential for night-time cooling

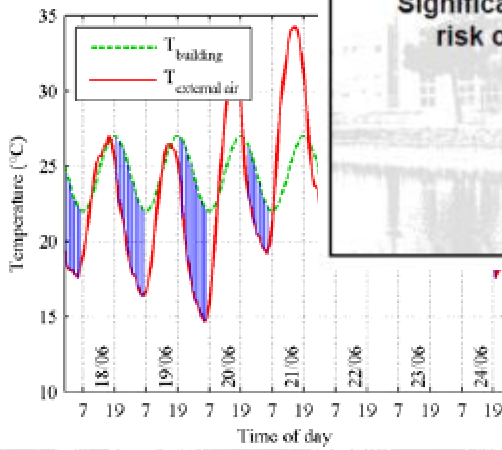
- Degree hours method to quantify the climatic cooling potential (CCP)
- Harmonically oscillating building temperature within a range of thermal comfort:

  $T_b = 24.5°C \pm 2.5°C$
- Ventilation period:

  7 pm – 7 am
- Minimum temperature difference:

  $\Delta T_{crit} = 3K$

→ CCP (K h)



Shaded areas show the climatic cooling potential during one exceptionally hot week in summer 2003 for Zurich SMA (ANETZ data)

$$CCP_d = \sum_{t=t_i}^{t_f} m_{d,t}\left(T_{b(d,t)} - T_{e(d,t)}\right) \qquad \begin{cases} m = 1\,h & \text{if } T_b - T_e \geq \Delta T_{crit} \\ m = 0 & \text{if } T_b - T_e < \Delta T_{crit} \end{cases}$$

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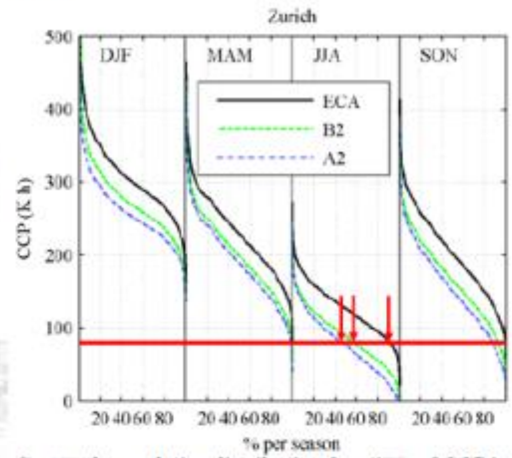
Cumulative distribution

Percentage of summer nights when CCP exceeds e.g. 80 Kh

- Current climate: 90 %
- Future climate: 45-55 %

Significant increase in risk of overheating



Seasonal cumulative distribution functions of CCP in Madrid for current climate (ECA data) and selected simulation runs with mean values for forcing scenarios A2 and B2

"Ventilative cooling potential of the outdoor air – now and in the future". Per Heiselberg Annex 62 Workshop Brussels March 2013

Long/Short term Climate - Cork

Month	Cork Airport TMY3 95th Percentile			CIT Stn. Summer 2013 95th Percentile**		
	G_h (Wh/m^2)	T_a (°C)	WS (m/s)	G_h (Wh/m^2)	T_a (°C)	WS (m/s)
May	742	17.2	10.0	730	16.0	6.3
June	815	19.5	9.3	826	20.6	5.0
July	707	20.7	9.0	795	25.0	4.3
August†	662	20.0	9.3	567	19.1	4.7
September*	574	19.4	9.0	-	-	-

† Data up to 15th August only for short term; *Data not yet available for short term; **Data taken from zero2020 weather station

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Annex Leadership & Participants

- **Annex Work Phase Jan 2014 – Dec 2016**
- **Annex write up phase Jan – Dec 2017**

- **Operating Agent:** Denmark, AAU, (Prof. Per Heiselberg)

- **Subtask A:**
  - Leader: Switzerland, ESTIA
  - Co-leader: Italy, EURAC
- **Subtask B:**
  - Leader: Austria, IBRI
  - Co-leader: Germany, RWTH Aachen
- **Subtask C:**
  - Leader: Greece, NKUA
  - Co-leader: China, Hunan University

Annex 62 Participants

Country	Institution	Subtask A	Subtask B	Subtask C	Probability	
Austria	IBRI		X	X	Certain	
Belgium	BBRI	X			Certain	
	Loeven			X	Low	
China	Hunan	X	X	X	Certain	
Denmark	AAU	X	X		Certain	
	DTU	X	X		Certain	
	VELUX	X	X	X	Certain	
	WindowMaster		X		Certain	
Finland	FIOH		X		Certain	
	SAMK	X			High	
Germany	RWTH Aachen	X	X		High	
Greece	NKUA	X	X	X	Certain	
Ireland	CIT		X	X	Certain	
Italy	EURAC	X			Certain	Yes
	POLIMI			X	Certain	
Japan	OSAKA	X	X	X	Certain	Yes
	Ritsumeikan	X	X	X	Certain	
Netherlands	Tu/e	X	X		Certain	No
	BBA Binnenm.	X			Certain	
	TUDelft	X			High	
Norway	NTNU		X	X	Certain	No
Sweden	LTH		X	X	Low	No
Switzerland	ESTIA	X			High	No
UK	Brunel		X	X	Certain	Yes
USA	MIT	X		X	High	No

Athens Workshop – Sept 23/24th 2013 (Coincided with 34th AIVC Conference & 1st Venticool Conference)

Definition of Ventilative Cooling

"Ventilative Cooling is the application (distribution in time and space) of ventilation air flow to reduce cooling loads in buildings. Ventilative Cooling utilizes the cooling and thermal perception potential (higher air velocities) of outdoor air. In Ventilative Cooling the air driving force can be natural, mechanical or a combination"

IEA-EBC Annex 62 text.

Annex 62 Objectives

- To **analyse, develop and evaluate suitable methods and tools** for prediction of cooling need, ventilative cooling performance and risk of overheating in buildings that are suitable for design purposes. (Subtask A).

- To give **guidelines for integration of ventilative cooling in energy performance calculation methods** and regulations including specification and verification of key performance indicators (Subtask A). ………

Annex 62 Objectives cont'd

- To extend the boundaries of existing ventilation solutions and their control strategies and **to develop recommendations for flexible and reliable ventilative cooling solutions** that can create comfortable conditions under a wide range of climatic conditions (Subtask B).

- To **demonstrate the performance of ventilative cooling solutions through analysis and evaluation** of well-documented case studies. (Subtask C).

Annex 62 Demarcation

The Annex will focus on (non exhaustive list):

- cooling and thermal perception potential of outdoor air.
- technical conditions needed to make ventilative cooling possible
- “large flow rate/high temp” and “small flow rate/low temp”
- impact of elevated air velocities & increased ventilation flow rates

Annex 62 Demarcation

- The Annex research focus will not be on solutions to increase the cooling potential of outdoor air by lowering its temperature through exploitation of heat exchange in earth ducts, ground water heat exchangers and similar technologies.
- The research focus will be on the exploitation of the cooling potential of untreated outdoor air.

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Annex 62 Organization

- Subtask A: Methods and Tools
- Subtask B: Solutions (CIT will Contribute)
- Subtask C: Case Studies (CIT will Contribute)

Subtask B & C

Subtask B (Solutions):

- Will investigate the cooling performance of existing mechanical, natural and hybrid ventilation systems and typical comfort control solutions as a starting point for extending the boundaries for their use.
- Will develop recommendations for flexible and reliable ventilative cooling solutions that can create comfort under a wide range of climatic conditions.

CIT will contribute to 6 of the 11 Activities in subtask B

Subtask C (Case Studies):

- The subtask will demonstrate the performance of ventilative cooling through analysis and evaluation of well-documented case studies.

CIT will contribute to 3 of the 9 Activities in subtask C

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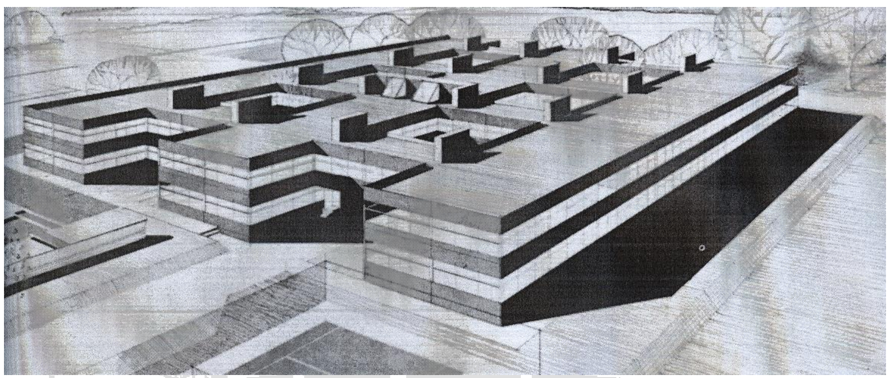
ZERo2020 overview

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.

ZERo2020 overview

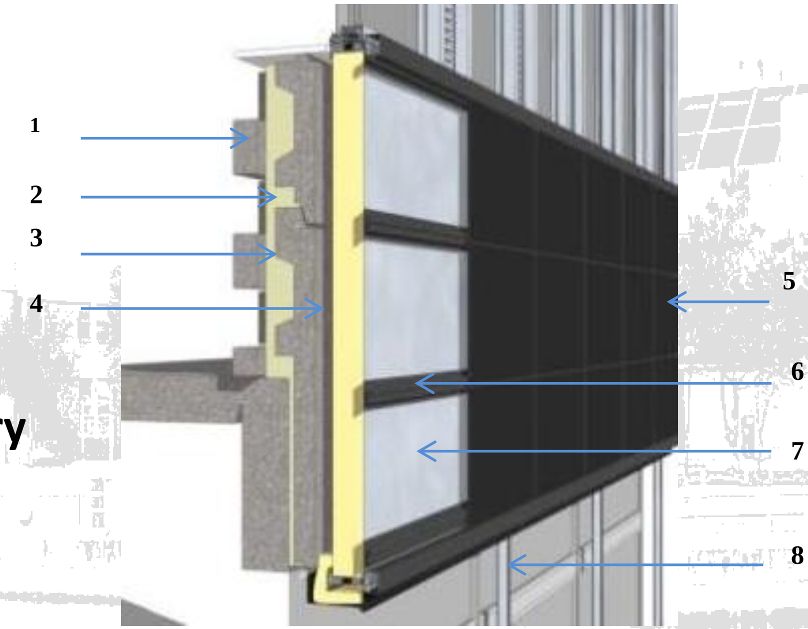
Opaque wall retrofit solution

Location	ω/φ (W/mK) / h	f (W/mK)	U_{wall} (W/m²K)	$U_{fenestr.}$ (W/m²K)
Control Space	5.49 / 1.017	0.608	3.633	6.0
Retrofit Space	5.92 / 0.963	0.004	0.090	0.84

<u>Opaque external wall retrofit details</u>

Component 1-4 existing structure boundary

Component 5-8 new external envelope boundary



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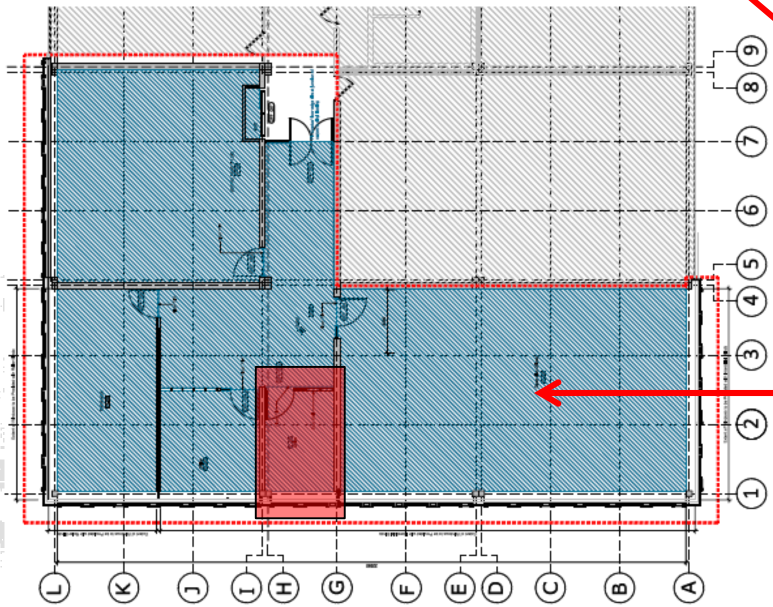
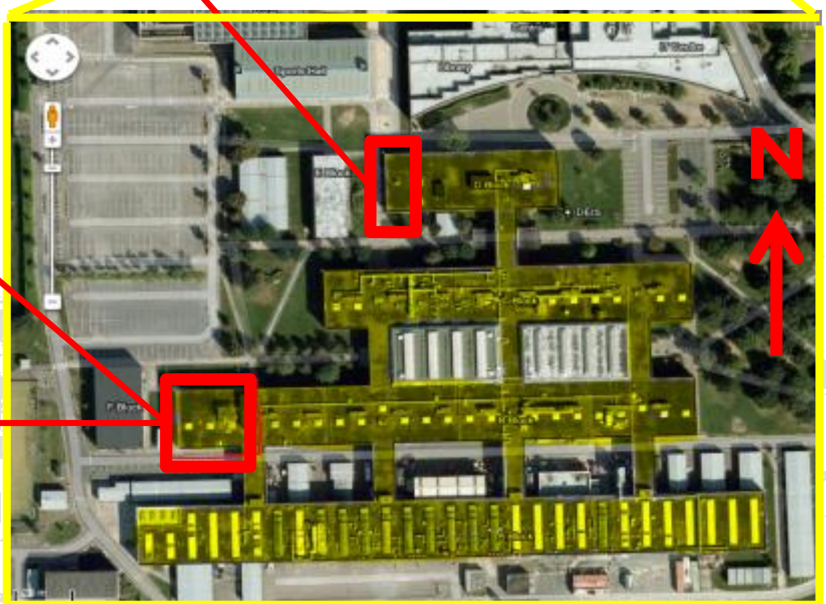
Control & Retrofit Spaces

west facing retrofit test space

West facing control space

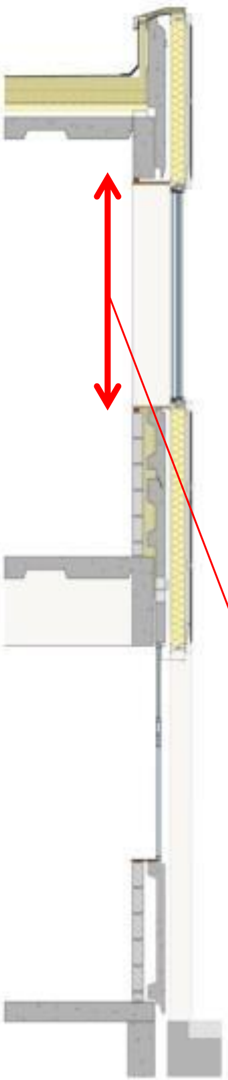
CIT Campus





29,000m² existing 1974 building wings A - D

Fenestration Module

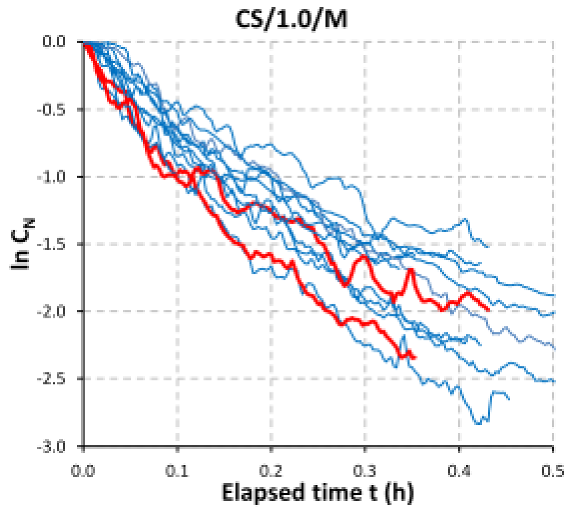


Limiting dimension for ventilation opening heights

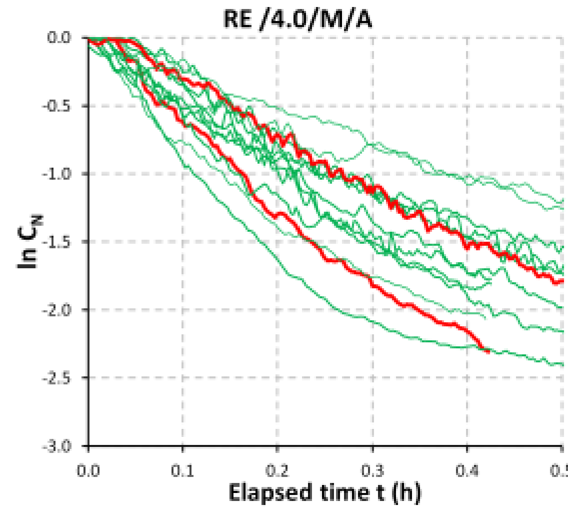
Modes of Operation
RE / 2 / M
RE / 3 / A
RE / 4 / M / A

Config & Tracer Conc Decay

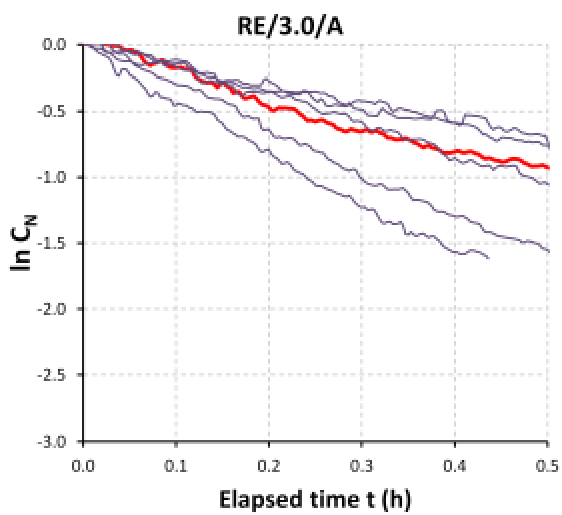
Tests	13
Max ACH	5.8
Min ACH	2.0
σ	1.2
Mean	3.7



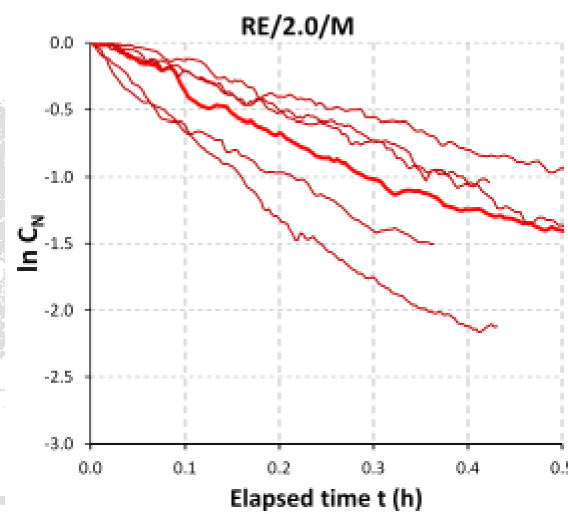
Tests	13
Max ACH	5.8
Min ACH	2.1
σ	1.0
Mean	3.1



Tests	6
Max ACH	3.4
Min ACH	1.5
σ	1.0
Mean	2.2



Tests	6
Max ACH	4.4
Min ACH	1.2
σ	1.2
Mean	2.7



Analysis of Dominant Forces

Inertia & Buoyancy forces were studied for each ventilation rate test with aim of establishing combined effect of wind and thermal conditions

Archimedes number, $Ar = (Gr/Re^2)$ described as:

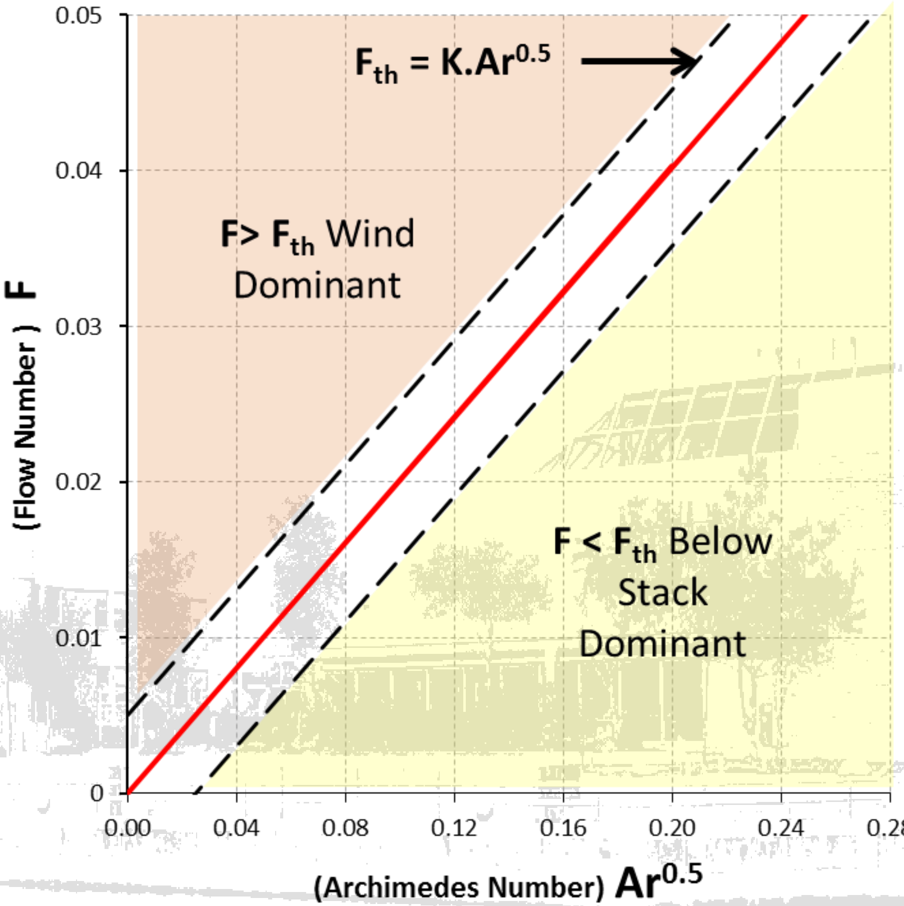
$$Ar^{0.5} = \frac{\Delta T g H}{T v_{wind}^2}$$

Dimensionless Flow number, F, described as:

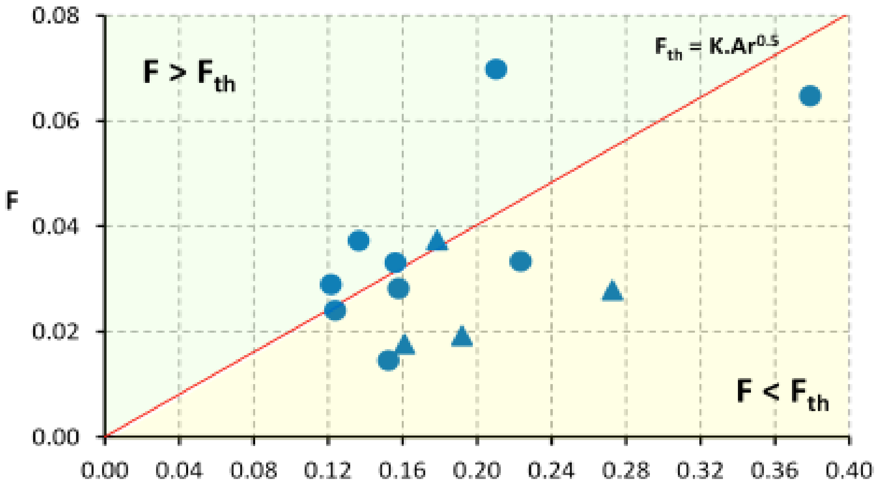
$$F = \frac{q_{ACH}}{A_{eff} v_{wind}}$$

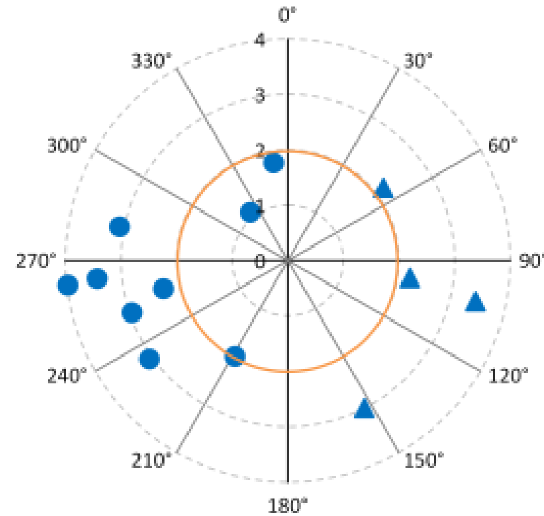
The use of a flow number due to thermal stack effect alone, F_{th}, is introduced to the plot.

$F_{th} = K.Ar^{0.5}$ **(Stack Dominant)**

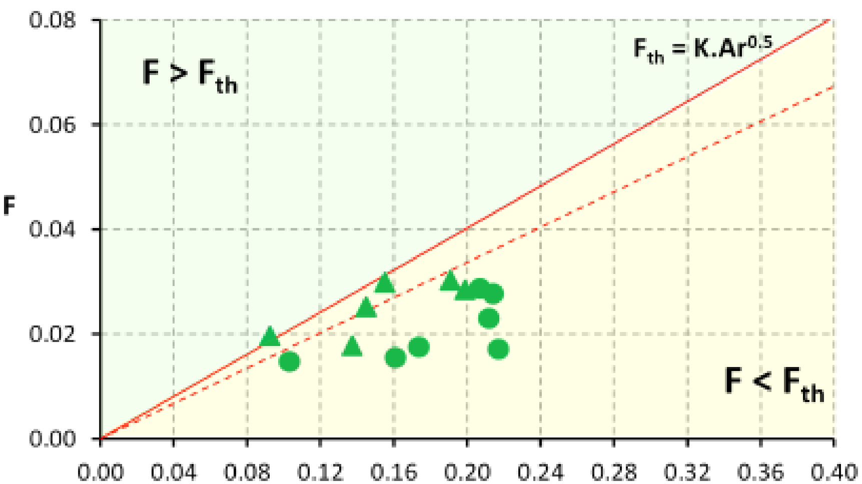


Warren Plot for CS1 & RE4

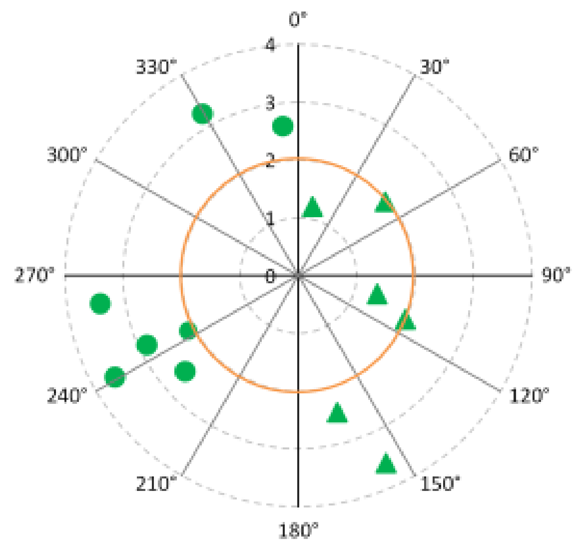




Control Space



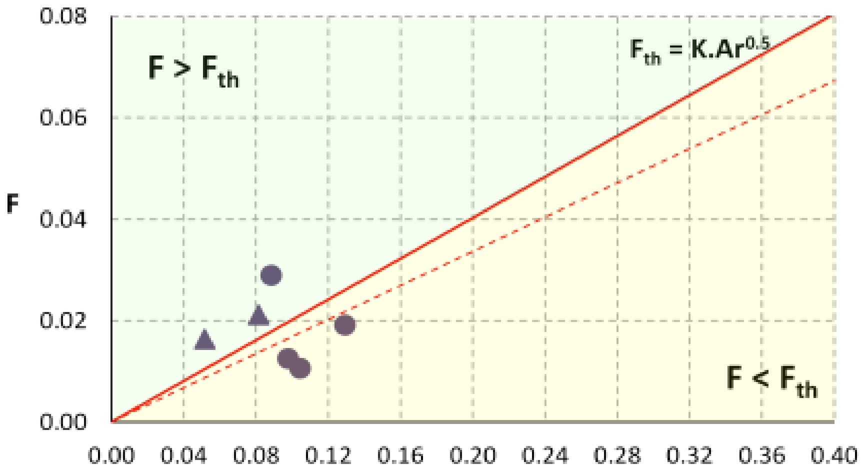
Archimedes Number $Ar^{0.5}$

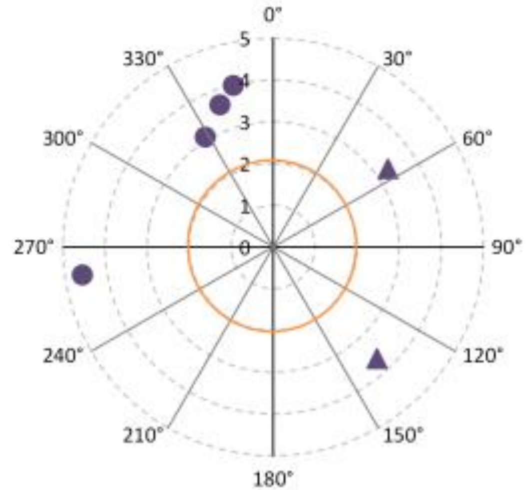


Test Wind Direction & Speed

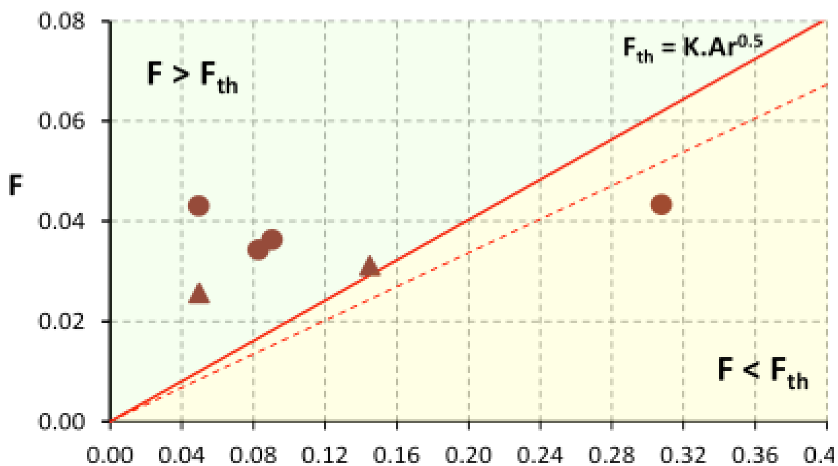
RE/4/M/A

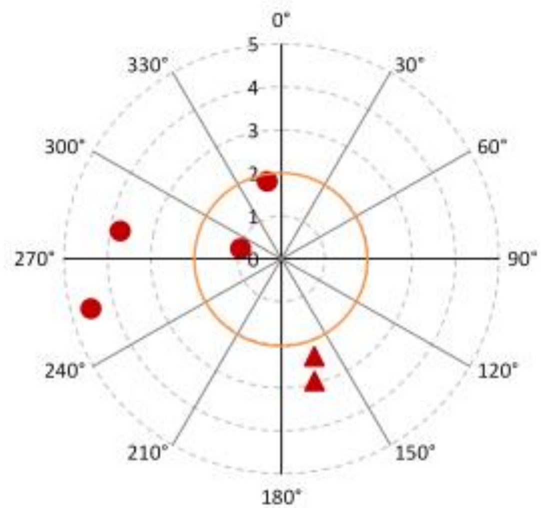
Warren Plot for RE2 & RE3





RE/3.0/A



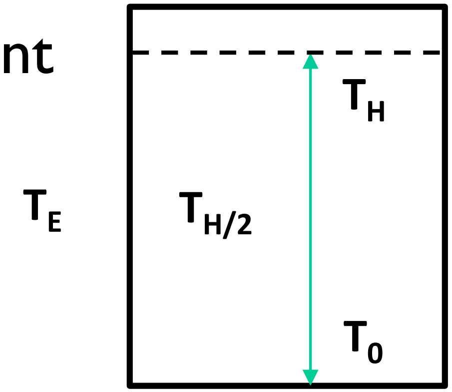


Archimedes Number Ar$^{0.5}$ **Test Wind Direction & Speed** **RE/2.0/M**

Analysis of Zonal Stratification

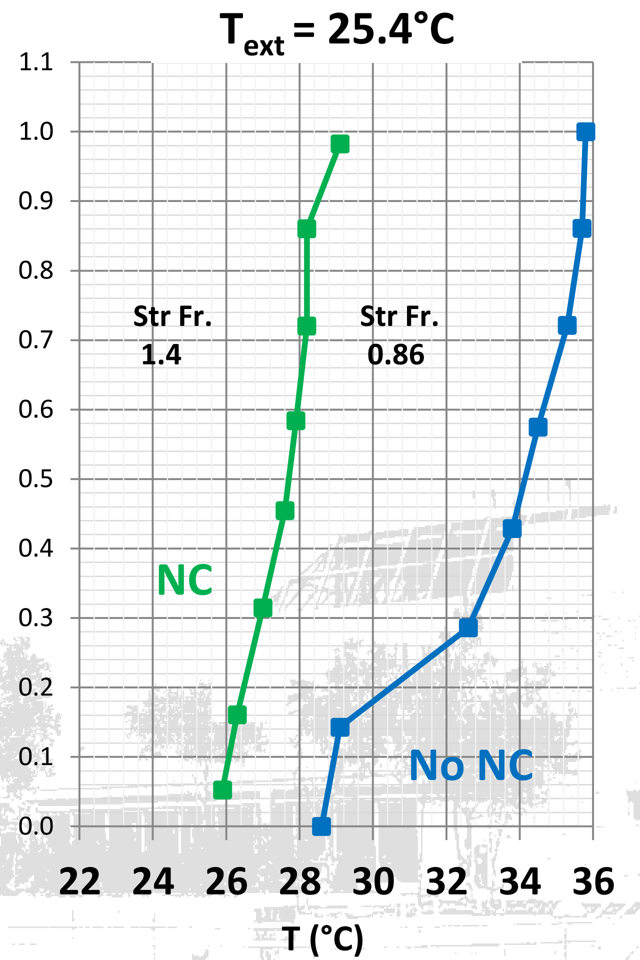
Str.Fr - Annex 35 HybVent

$$\frac{\Delta T_s}{\Delta T_{ie}} = \frac{T_H - T_0}{T_{H/2} - T_E}$$



StrFr Results for Test conditions close or equal to F_{th}

Config	Test	Str Fr	$\lvert F-F_{th} \rvert$	Km^{-1}
CS/1.0	3	0.227	0.002	0.49
CS/1.0	4	0.551	0.002	0.94
CS/1.0	27	0.565	0.001	1.00
CS/1.0	2	0.621	0.003	1.81
RE/2.0	29	0.700	0.002	1.30
CS/1.0	14	1.051	0.003	3.20
RE/3.0	25	1.111	0.002	1.20
RE/3.0	16	1.125	0.004	0.60
RE/4.0	32	1.438	0.001	0.80
RE/4.0	24	1.809	0.000	1.20



RE vs. CS stratification

Summary of Strat Factor Data

Analysis of overheating criteria retrofit and control space

Space.	hrs>25°C (%Σhrs)*	hrs>28°C (%Σhrs)*
Control	34	**17**
Retrofit	33	**3.5**

Based on 981 working hours May-September

20th June – 19th July 2013 Values *Str.Fr* (*$\Delta T_s/\Delta T_{ie}$*) Data

Space.	Occupied hours (09:00-18:00)				Unoccupied Hours (18:00-09:00)			
	50th	75th	95th	**% occ hrs >1**	50th	75th	95th	% occ hrs>1
Control	0.411	0.691	1.19	**9.0%**	0.192	0.333	0.622	0.0%
Retrofit	0.202	0.609	2.59	**14.5%**	0.157	0.290	0.611	2.2%

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Planned Annex work at zero2020

- More detailed study of single side ventilation rates
  - using wind measurements in 3D at approx. 32hz frequency
  - Age of air tests in ventilated zone
  - Air speeds at the inlet (some tests done a 1 minute test interval)
- Develop TRNSYS/COMIS multi-zone model for testbed
- Develop zonal flow model single zone using TRNSYS environ
- Investigate climate cooling potential for Irish Climate (NZEB)
- Study thermal perception potential for single sided ventilation

Summary

- Cooling increasingly important due to low energy buildings
- VC utilises thermal perception potential of untreated outdoor air
- Annex 62 addresses a range of requirements regarding VC technology (methods, modelling, applications, regulations)
- CIT will contribute using zero2020 low energy retrofit testbed

Thank You