## Ventilative Cooling in Buildings: Now & In The Future
## BBRI Institute 23rd October 2017

# Design and Performance of Ventilative Cooling: A Review of Principals, Strategies and Components from International Case Studies

**Paul D O'Sullivan**
Cork Institute of Technology


agenda

EBC

CORK INSTITUTE OF TECHNOLOGY

- **Annex 62 & Subtask C**
- **Climate**
- **Overview of Contributions**
- **Design Influences**
- **Building Characteristics**
- **VC Strategies**
- **Control Strategies**
- **Design Criteria, Simulation and Overheating risk**
- **Lessons Learned**
- **Brochure & Dissemination**

# Well Documented Case Studies of VC
# Annex 62 – Sub Task C

## Objectives of Annex 62 - STC

To fulfil the scope of the Annex and to make energy-efficient use of ventilative cooling (air-based systems) the preferred solution the Annex focuses on the following specific 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).
- 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).**

## Objectives of Annex 62 - STC

- Activity C.1.

**Analysis and evaluation** of performance of ventilative cooling solutions and of used design methods and tools using similar criteria and methods

- Activity C.2.

**Lessons learned and development of recommendations** for design and operation of ventilative cooling as well as identification of barriers for application and functioning.

## What Climates Are Covered In The Case Studies?

# Climate of Case Studies

**Variation in climate regions for all case study buildings.**
(Please refer to the Koppen-Geiger climate classification system for details on KG abbreviations in column 1)

| K-G | General Description | Qty | Locations |
|---|---|---|---|
| **Cfb** | Temperate with warm summers and no dry season | 5 | Cork, IE; Ernstbrunn, AT; Waregemand Ghent, BE; Verrieres-le-Buisson, FR; Bristol, UK |
| **Cfa** | Temperate, hot summers and no dry season | 3 | Changsha, CN; Hayama, JP |
| **Dfb** | Cold with warm summers and no dry season | 3 | Stavern, NO; Trondheim, NO; Innsbruck, AT |
| **Dfc** | Cold with no dry season and cold summer | 1 | Larvik, NO |
| **Csa** | Temperate with dry, hot summers | 2 | Sicily, IT; Lisbon PT |

# Who, Where, What, When?

## Contributions

| Country | Building Name | Building Type | Year | Floor Area m² | Strategy |
|---|---|---|---|---|---|
| **IE** | zero2020 | Office | 2012(R) | 223 | Natural |
| **NO** | Brunla Primary school | Education | 2011(R) | 2500 | Hybrid |
| **NO** | Solstad barnehage | Kindergarten | 2011(N) | 788 | Hybrid |
| **AT** | UNI Innsbruck | Education | 2014(R) | 12,530 | Hybrid |
| **AT** | wk Simonsfeld | Office | 2014(N) | 967 | Hybrid |
| **BE** | Renson | Office | 2003(N) | 2107 | Natural |
| **BE** | KU Leuven Ghent | Education | 2012(N) | 278 | Hybrid |
| **JP** | Nexus Hayama | Mixed Use | 2011(N) | 12,836 | Natural |
| **JP** | GFO Building Osaka | Office | 2013(N) | 394,000 | Hybrid |
| **PT** | CML Kindergarden | Education | 2013(N) | 680 | Natural |
| **UK** | Bristol University | Education | 2013(R) | 117 | Mechanical |

| Country | Building Name | Building Type | Year | Floor Area m² | Strategy |
|---|---|---|---|---|---|
| **CN** | Wanguo MOMA | Residential | 2007(N) | 1109 | Mechanical |
| **FR** | Maison Air et Lumiere | House | 2011(N) | 173 | Natural |
| **IT** | Mascalucia ZEB | House | 2013(N) | 144 | Hybrid |
| **NO** | Living Lab | Residential | 2014(N) | 100 | Hybrid |

# What were the design influences for Ventilative Cooling ?

## Design Influences

| Country | | Building | Lower Initial costs | Lower Maintenance Costs | Lower Energy Costs | Reducing Solar Loads | Reducing Internal Loads | Reducing External Noise | High Internal noise propagation | Elevated Air Pollution | Avoiding Rain Ingress | Insect Prevention | Burglary Prevention | Reduced Privacy | Air Leakage |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IE | **R** | zero2020 | H | M | H | H | L | L | L | L | M | L | H | M | M |
| NO | **R** | Brunla Primary school | H | H | H | L | M | L | L | H | M | L | L | L | H |
| NO | **R** | Solstad barnehage | L | L | H | L | L | L | M | H | L | L | L | L | H |
| AT | **U** | UNI Innsbruck | H | H | H | M | L | M | L | L | M | L | L | L | H |
| AT | **R** | wk Simonsfeld | H | H | H | M | L | L | L | L | L | L | L | L | M |
| BE | **R** | Renson | L | M | L | H | H | H | L | L | L | L | L | L | L |
| BE | **U** | KU Leuven Ghent | H | L | H | H | H | L | L | L | M | L | L | L | H |
| JP | **R** | Nexus Hayama | M | M | H | H | L | L | L | L | M | H | H | M | M |
| JP | **U** | GFO Building | H | M | L | L | L | L | L | L | L | L | L | L | L |
| PT | **U** | CML Kindergarden | H | L | L | M | M | L | L | L | M | M | M | M | L |
| UK | **R** | Bristol University | H | H | H | L | H | L | M | L | M | M | H | L | L |
| CN | **U** | Wanguo MOMA | H | M | H | H | L | L | L | L | M | L | M | L | H |
| FR | **U** | Maison Air et Lumiere | M | M | L | H | M | L | L | H | L | L | M | L | M |
| IT | **R** | Mascalucia ZEB | H | M | H | H | L | L | L | L | L | L | M | L | M |
| NO | **U** | Living Lab | L | L | H | H | M | L | M | L | H | L | L | L | H |

# How did We Do VC?

## Ventilative Cooling Strategies

EBC

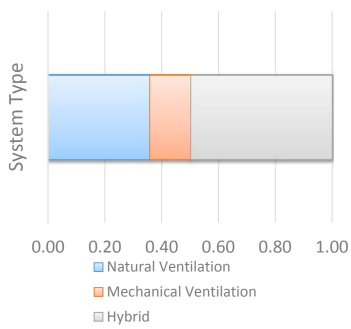
| Ventilative cooling Concepts | Natural driven | Mech. Supply Driven | Mech. exhaust driven | Natural night ventilation | Mech. night ventilation | Air conditioning | Indirect Evap. Cooling | Earth to Air Heat Exch. | Phase Chang eMaterials |
|---|---|---|---|---|---|---|---|---|---|
| zero2020 (IE) | X | | | X | | | | | |
| Brunla Primary school (NO) | X | | | X | | | | | |
| Solstad barnehage (NO) | X | | X | X | X | | | | |
| UNI Innsbruck (AT) | X | | X | X | | | | | |
| wk Simonsfeld (AT) | X | | X | | | | | | |
| Renson (BE) | X | | | X | | | | | |
| KU Leuven Ghent (BE) | X | | X | | | | X | | |
| Nexus Hayama (JP) | X | | | | | X | | | |
| GFO Building (JP) | X | X | X | | | X | | | |
| CML Kindergarden (PT) | X | | | X | | | | | |
| Bristol University (UK) | | | | | X | X | | | X |
| Wanguo MOMA (CN) | | X | X | | X | X | | | |
| Maison Air et Lumiere (FR) | X | | | | | | | | |
| Mascalucia ZEB (IT) | X | | | X | | | | X | |
| Living Lab (NO) | X | | | | | | | | |

## Ventilative Cooling Strategies

EBC

# Summary points

- 86%, of the case studies use natural ventilation in their VC strategy
- Generally, sensible internal loads for NV ≤ 30 $Wm^{-2}$. (Average is 25 $Wm^{-2}$.)
- No. of Days with a maximum daily external temperature ≥ 25°C was ≤ 30 in all cases except Portugal
- Hybrid VC most prevalent strategy with 50% of buildings using this approach
- The internal loads in Hybrid spaces were ≥ 40 $Wm^{-2}$ in Norway and Belgium, in Austria & Italy they were ≤ 10 $Wm^{-2}$

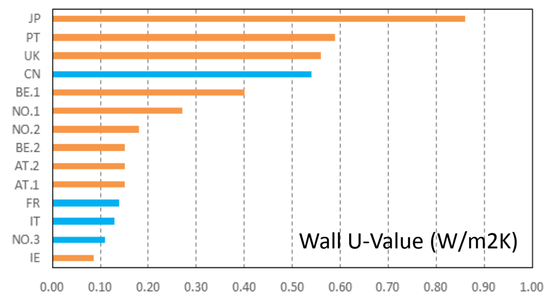


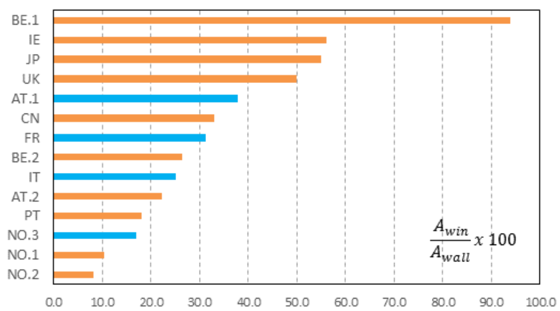
EBC

# What Were the Building Characteristics?

## Building Characteristics

EBC

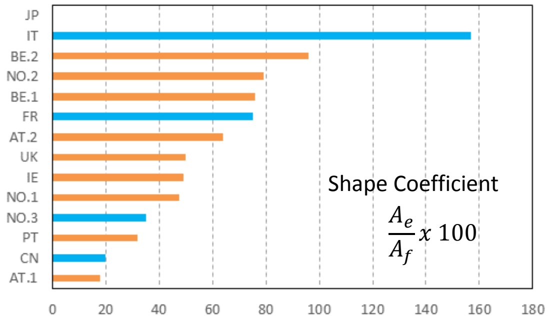



- Mean elemental U-value is 0.41 W/m²K
- standard deviation is 0.34 W/m²K
- Six case studies heavy /very heavy thermal mass (ISO13790)
- Average infiltration at 1.13 $h^{-1}$, (0.51 to 1.85 $h^{-1}$)
- Average window/wall area ratio is 34%.
- Four case studies area ratios greater than 50%

- Some very good and very poor thermal performance
- Large variation in building shapes
- Norwegian case studies lowest window/wall ratios
- Belgium Offices from 2003 almost exclusively glass

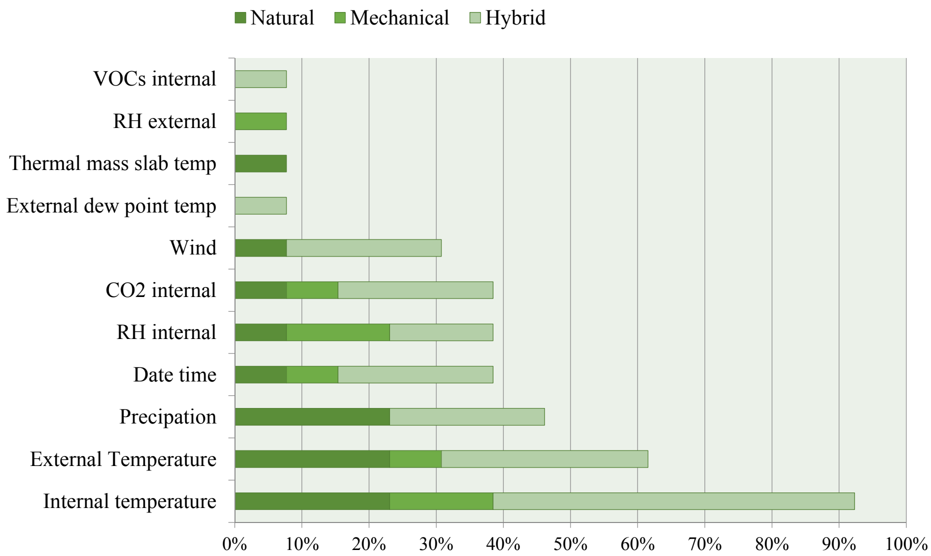
## Building Characteristics



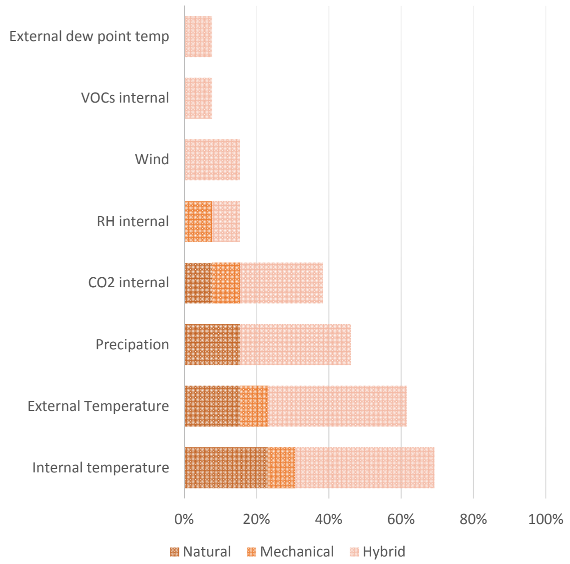

- Minimum shape coefficient of 0.18
- Maximum shape coefficient of 0.96
- Italian home has very high shape coefficient

# How Do We Control VC?

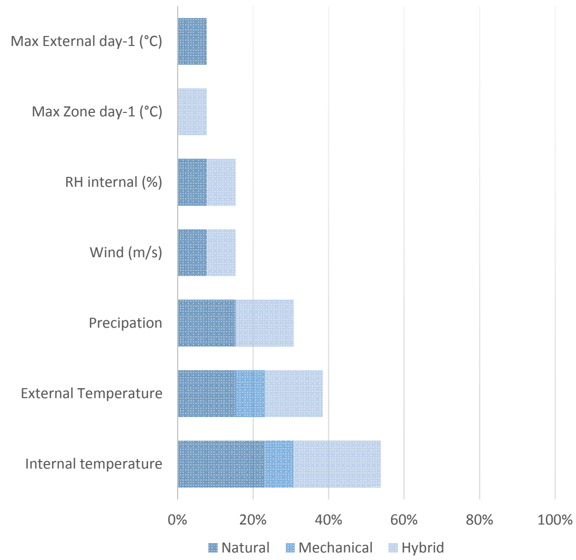
## Control Strategies - Overall




## Control Strategies – Occupied & Night Vent




**Occupied Hours**




**Night time ventilation**

Control Strategies - Summary

## Summary points

- **Temperature** and **RH** were the **main parameters** used ($CO_2$ for IAQ).
- Internal temperature used by all cases studies with set-point control
- Mean internal air temperature set-point was around 22°C. (20-24°C)
- Over 60% of case studies use **external temp** as a **low temp limit**
- Mean external low temperature limit set-point 14°C. (10-18°C)

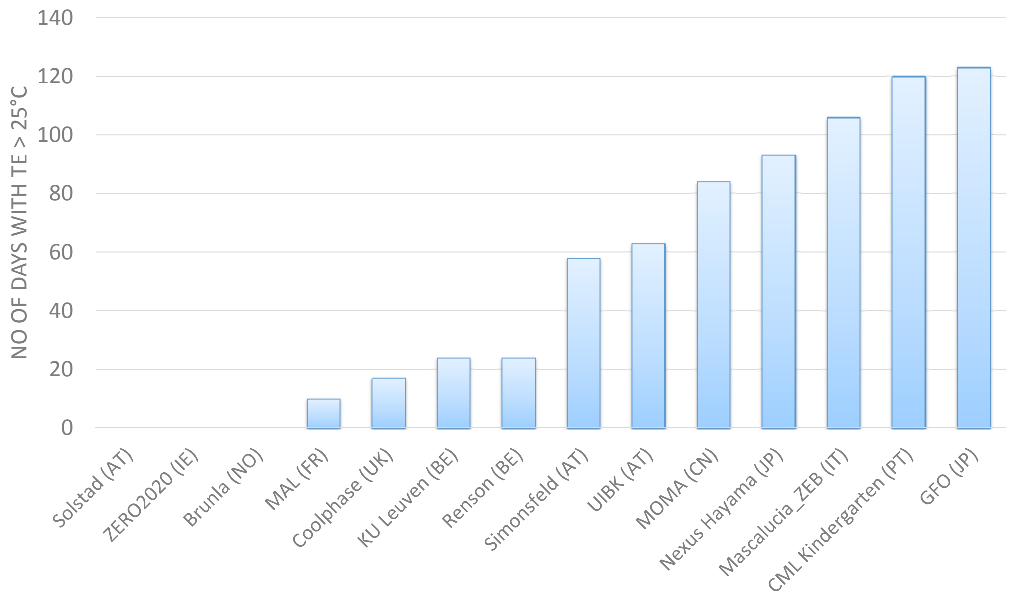
Control Strategies - Summary

## Summary points

- All NV case studies had occupant interaction with the VC system
- Only 60% of hybrid systems had this interaction.
- 69% of the case studies had a night ventilation strategy
- Wind speed had to be ≤ 10m/s with no rain for night ventilation systems

## How Have these Buildings Performed?

## Climate Indicator



## Design Criteria & Overheating

EBC

### Preliminary results of VC performance evaluation

| Country | Building | Summer Design Values | | overheating criteria | % Occ hrs above threshold | | Occ hrs |
|---|---|---|---|---|---|---|---|
| | | $T_e$ | $T_{i,o}$ | | 28°C | 25°C | |
| **IE** | zero2020 | 26.0 | 25.0 | $T_i$ < 28°Cfor 99% occ hrs | 0.7 | 5.5 | 2600 |
| **NO.1** | BrunlaSchool | 25.0 | 26.0 | $T_i$ > 26°C | 0.0 | 0.0 | 2600 |
| **NO.2** | Solstad | 25.0 | 24.0 | $T_i$ > 26°C | 0.0 | 0.0 | 2860 |
| **AT.1** | UNI Innsbruck | 34.0 | 27.0 | $T_i$ < 26°C for 95% occ hrs | 1.1 | 16.2 | 2600 |
| **AT.2** | wkSimonsfeld | 34.5 | 24.0 | $T_i$ > 26°C zone / T > 29°C gallery | 0.0 | 5.0 | 3250 |
| **JP** | Nexus Hayama | 26.0 | 26.0 | $T_i$ < 28°C for 99% occ hrs (check) | 1.0 | 40.0 | 8736 |
| **PT** | Kindergarden | 30.0 | 26.0 | 80% acceptability for 99% hr occ | 2.6 | 16.0 | 3640 |

EBC

# How are We Simulating VC?

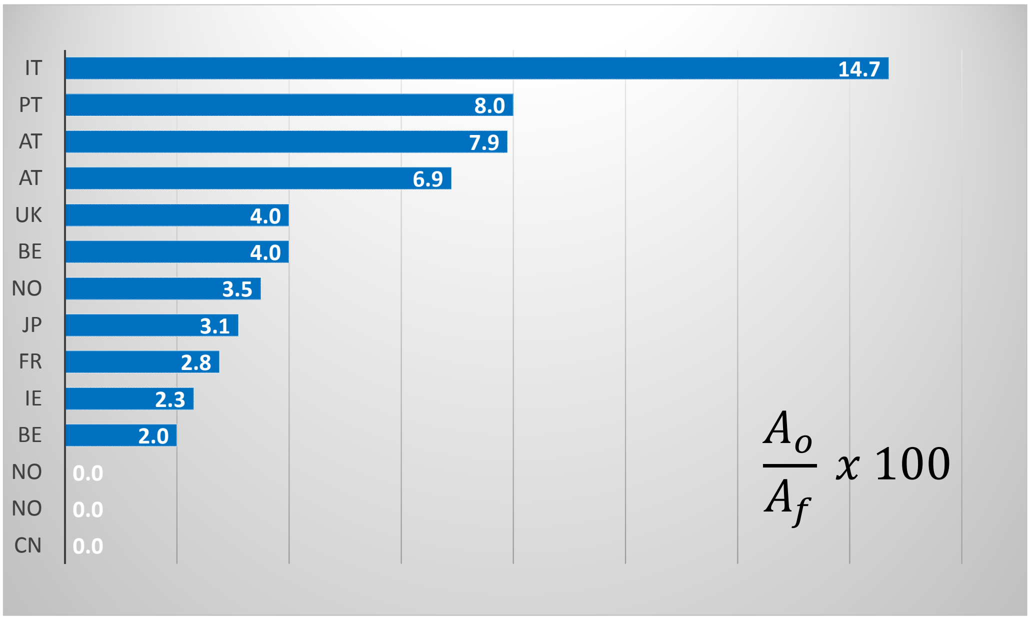
## Design Simulation

| Scope Development | Concept Design | Detailed Design | Performance Analysis |
|---|---|---|---|
| IE CIBSE Guide A | CIBSE Admittance | IES Apache /Macro | TRNSYS / PHPP / R |
| NO NS 3700 | SIMIEN | Windmaster/SIMIEN | IDA Ice |
| NO NS 3700 | SIMIEN | Windmaster / SIMIEN | IDA Ice |
| PHPP | Dynbil | TRNSYS | TRNSYS |
| TAS 9.2 | TAS 9.2 | TAS 9.2 | PHPP |
| - | CAPSOL | - | - |
| RT2005 F | VELUX Daylight Vis. | Bsim (DK) | RT2012 |
| PHPP | PHPP | EnergyPlus + GenOpt | PHPP |
| CASBEE | BEST/CFD/STREAM | CFD / STREAM | - |
| EnergyPlus | EnergyPlus | EnergyPlus | EnergyPlus |
| CIBSE Guide A | EFA / CIBSE TM 52 | IES Apache | IES Apache |
| - | SIMIEN | - | IDA Ice |

UK & IE – IES and CIBSE
NO – IDA ICE
IT, AT & IE – PHPP
PT - EnergyPlus

What about the Percentage Opening Area to Floor Area Ratio? A Key VC Metric?

## Key Design Metrics – POF Ratio




# What Lessons did We Learn?

Lessons Learned

# Design and Construction

- **Detailed building simulation is important when simulating ventilative cooling strategies.** Most case studies analysed highlighted the need for reliable building simulations in the design phase of a ventilative cooling system. This was considered most important when designing for hybrid ventilation strategies where multiple mechanical systems need harmonization.
- Some studies also said that **simulating the window opening in detail was important**.
- **Customisation may be an important factor in when designing a ventilative cooling system**. In order to ventilate certain buildings it may be necessary to design custom components. Some case studies highlighted the need to have custom design systems that were specific to country regulations and the use of a building or space.

Lessons Learned

# Design and Construction

- Some consideration should also be given to the **clients expectations** around specific issues like **rain ingress and insect prevention**.
- **Ventilative cooling systems were considered cost-effective and energy efficient in design** by most case studies, but **particularly with naturally ventilated systems.** It was indicated that designing with the integration of manual operation and control was important, particularly in a domestic setting.

# Operation

- **Engaging with the building owners or operators as soon as possible is integral to guaranteeing building performance for IAQ, comfort or energy savings**. For some case studies this specifically meant educating or working with the facilities operator or manager for the building, for others it meant educating the building occupiers themselves.
- It was suggested by some that this **engagement should be as early as the design stage**.



Operation

- **VC in operation is generally a good option**. Case studies comment on the reduction of overheating and improvement of comfort conditions in the buildings that used outside air. However **correct maintenance and calibration of the systems is integral to maintaining performance.**
- Some case studies highlighted the need to **exploit the outside air more with lower external air control limits** during typical and night-time operation.
- Others suggested that **exploiting the thermal mass of a building was key.** However it was noted that care must be taken with considering these low temperatures as some case studies, particularly in cold climates observed more incidences of overcooling than overheating.

## Case Study Brochure

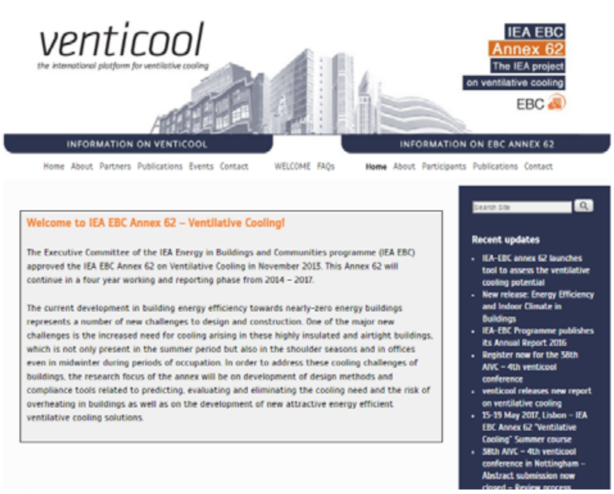
EBC | Cork Institute of Technology

| Pg | Information |
|---|---|
| 1 | Introduction, Local Climate & Key Information |
| 2 | Building Information & Design Influences |
| 3 | Energy Systems |
| 4 | Ventilative Cooling Principles and Components |
| 5 | Control Strategy overview and description |
| 6 | Design stage simulation, design criteria |
| 7-9 | Performance Evaluation |
| 10 | Lessons Learned |
| 11 | References & Project Contacts |

## Dissemination

EBC | Cork Institute of Technology

- All brochures will be available at the IEA-EBC Annex 62 website
- Planned for December 2017
- A summary document also available
  - Overview with key data distilled into important findings
  - Key lessons learned
  - Recommendations




http://venticool.eu/annex-62-publications/deliverables/

Dissemination

Stay Tuned for Updates! Thank You