National Building Energy Retrofit Testbed

An online, open source information and data platform for education and research in low energy building retrofit

Summary Report

SEAI RD&D Project RDD/00116

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Table of Contents

Index of Figures & Tables

Executive Summary

This following report is a summary of the outcomes for the National Building Energy Retrofit Testbed (NBERT) online portal, SEAI RD&D project RDD/00116. The NBERT data portal provides an online platform where information and data can be accessed for the NBERT at CIT. There is also an online Ventilative Cooling Potential Analysis (VCPA) tool available as part of the platform.

One of the largest or most significant challenges facing the building sector in Ireland, the European Union (EU) and internationally is the energy efficient retrofit of the existing building stock. As EU member states are required to make energy efficiency improvements every decade in the building area the majority of this will inevitably come from reducing consumption in the existing building stock. Marnay et al [1] estimated that half of the buildings in use in 2050 have already been constructed highlighting the role existing buildings must play in climate change mitigation actions. In Europe, these existing buildings already account for 40% of energy consumption [2]. In Ireland this contribution is 27% [3].The targets issued by the EU can be summarised as follow:

- 20% improvement energy efficiency by 2020
- 33% improvement energy efficiency in public buildings by 2020
- 40% reduction in emissions by 2030
- 80% reduction in emissions by 2050

In Ireland, the need for public buildings to act as exemplar demonstrations has led to the demand to set examples of nearly zero energy buildings (nZEB) [4]. These targets, in part, resulted in the design and construction of the zero2020 building. In 2012 Cork Institute of Technology (CIT) completed a pilot project for a low energy retrofit of their existing 29,000m^2 teaching building constructed in 1974 [5]. The retrofit pilot covered 222m^2 of the building. The completed zero2020 building now hosts the NBERT. NBERT is a highly instrumented test-bed which generates long term monitoring performance data and also, due to the development of the online platform within this project, allows researchers and students access to a real world case study of a successful and high performance retrofit. NBERT gives researchers access to data and detailed building information via the web-based platform.

There are three main components of the NBERT project:

1. Provide an online, publicly accessible repository of information for the zero2020/NBERT project including interactive information in downloadable format.
2. Provide access to a data portal that houses 4 years of raw measurement data covering internal environment, weather data and energy systems performance data
3. Provide an online tool for investigating Ventilative Cooling (VC) Potential for the Irish situation.

To date there has been 6 PhDs undertaken at NBERT, over 100 undergraduates have used NBERT in their course modules, NBERT has received awards for sustainability, and has been selected as a case study for an International Energy Agency project relating to VC [6]. The new information portal is intended to further increase the use of NBERT as an educational and research resource in low energy building retrofit. It will act as an information hub for those interested in high performance building envelope retrofit.

This summary report for NBERT is structured as follows. Section 1 is an overview of the NBERT online platform. It describes the design, objectives and use of the platform. Section 2 describes the information portal while section 3 reports the data portal. Section 4 talks about the VCPA tool.

Dissemination

Two articles relating to aspects of the NBERT project have been accepted for presentation at international scientific conferences. One conference is a leading conference for engineering education while the second conference subject matter is in low energy building performance, building cooling and ventilation technology. Full papers from the conference proceedings are not as yet available. Details regarding both are below. It is envisaged conference proceedings for both will be available in October 2018. For further information please contact nbertresearch@gmail.com directly.

- P.D. O'Sullivan., A. O'Donovan., *NBERT: A open source, information and learning resource for engineering education in the built environment disciplines*, Proceedings of 45th SEFI Conference, Sept 2018, DTU, Denmark
- P.D. O'Sullivan., M. D. Murphy., J. Pittam., A. O'Donovan., *Climate cooling potential of exposed thermal mass coupled with single sided ventilation in low energy buildings in Northern European climates*, Proceedings of 39th AIVC & 5th Venticool Conference, Sept 2018, Antibes, France

In addition to the above dissemination documents an official launch of the NBERT Online Platform is planned for September 2018 at CIT. For further information please contact nbertresearch@gmail.com directly.

Introduction

NBERT at zero2020 in CIT is a low energy and passively cooled retrofit testbed that was completed in 2012 with high-resolution data logging capabilities [7]. The specific aspects of the NBERT project related to the SEAI RD&D project covered here involves development of an e-learning virtual environment comprising an online information portal for the zero2020 building, development of an online data portal with 4 years of data and the provision of a VC assessment tool.

The original zero2020 project scope consisted of design and installation of a structurally independent external envelope solution. The target was to deliver a building with a very low energy performance and a high level of occupant satisfaction with the internal environment. Due to the nature of retrofit in live buildings, solutions have to be phased and as non-invasive as possible, with solutions that also can deal with large scale urban retrofit in both residential and non-residential scenarios [8], [9]. Therefore a phased, modular, scalable, flexible and durable external retrofit with an intermediate internal retrofit was the most suitable design solution (coupled with a largely off-site build). The primary aim of the envelope upgrade was to extend the lifetime of the building and ensure low thermal energy demand and improved occupant comfort.

Following on from the zero2020 project, which now forms part of the NBERT physical infrastructure, the new SEAI funded online platform provides two separate complimentary functions. Firstly, it provides all detailed geometric, thermophysical and parametric information regarding the NBERT building in interactive form. All recorded long-term measurement data at the building covering: energy systems, internal environmental parameters, and local building weather data are available in a relational database. Attention is given to analysis functionality for VC performance at the building and in the assessment of energy and thermal comfort performance. Secondly, to allow more general application, a VCPA tool is provided for assessing the cooling potential of ventilation systems in the Irish climate that do not utilise mechanical cooling energy. VC is a key strategy in low energy buildings and a performance assessment tool supports the recommendation for the use of natural ventilation in the upcoming Part L for non-domestic buildings. The portal delivers an open source tool available for use by the building research community.

A. Virtual learning environments for the built environment disciplines

One of the possible benefits to the education research community from the new information and data portal is in the development of building energy models and their associated calibration. Many whole building energy simulation tools have been validated for use in the area of energy consumption simulation [10]. However, when these tools are not calibrated discrepancies between actual and simulated energy consumption of ±30% are seen [11]. One of the main issues associated with building energy and environmental simulations is related to their complexity [12]. Whether a manual or automated approach is adopted for model calibration, a large quantity of data is often required, or some data may not be available for a given building [13]. The challenge for the building modeller can also lie in the scale of data collected in a building and the quality of the data generated. The NBERT project has a manageable scale of data that makes it easier to use for these purposes. The concept of a live building testbed is well established at NBERT.

In an educational context, research into virtual learning environments has been discussed in engineering education (EE) for over a decade. The virtual e-learning platforms created or conceptualised in the past fostered environments for all to upskill, over a flexible length of time, while allowing students to select an education path that was tailor made and personalised. Many research studies have highlighted the benefits of virtual learning environments for enhancing the student experience in engineering education [14] [15]. Nowadays the "emerging leaders" in engineering education are using open and online e-learning platforms to put the student first, by focusing on "socially-relevant" and personalised projects to contribute to the increasing need for multidisciplinary learning and a global impact [16]. One resource that can be vital in assisting and enhancing the student experience in virtual or traditional teaching environments is the availability of data and information for project based learning (PBL). While the open source data and information community is expanding, large datasets can often be overwhelming to manage [17]. Datasets that are student suitable need elements of visualisation, selection functionality and would be more useful if they were designed or integrated to compliment modules or courses. One of the most socially relevant topics facing the field of engineering today is the challenge of improving the energy efficiency in our building stock. In Europe, the targets for buildings are very ambitious, with an 80-90% reduction in carbon emissions anticipated by the year 2050 [18]. To meet this, all new buildings are expected to be nearly zero energy buildings (nZEBs) by the year 2020. Retrofitting of the existing building stock will also be necessary to meet these targets. Unfortunately, examples of well documented building energy retrofit case studies are sparse, resulting in limited potential to develop assessments using data and detailed information from real, occupied buildings. The NBERT learning and information resource acts as a virtual laboratory and presents interactive high resolution data and information from NBERT. The online suite of tools can be used by educators, anywhere in the world, as a basis for the development of energy models and undertaking analysis of performance in a real world application. The learning resource attempts to streamline the pedagogical style in the classroom, enabling students to engage in the development of energy models and analysis based assessments in an exploratory and more fluid manner, to improve the student learning experience.

B. Ventilative Cooling and climate cooling potential

There can be unintended consequences to the drive for delivering high thermal performance nZEBs [19]. Even in Northern European climates, internal overheating in many nZEBs is a barrier to year round occupant satisfaction with the indoor thermal environment [20]. Improved energy performance and enhanced thermal comfort should not be perceived as a rigid dichotomy of concepts. However, an acceptable thermal environment, during extended cooling periods now present in nZEB's, can come at a high energy cost if mechanical cooling is used. Passive Ventilative Cooling (VC) through the integration of natural ventilation principles with the building morphology and materials has long been championed as a viable alternative to mechanical cooling [21]. NBERT uses a novel multi configuration slotted louvre system to provide passive VC year round [22], [23]. As part of the NBERT project an online VCPA tool was also developed as an early stage assessment tool for designers and as an educational resource for engineering students. The VCPA tool is based on the work in the International Energy Agency project IEA-EBC Annex 62 VC.

The portal will be of use to both educators, researchers and professional seeking information about the zero2020 project and to access data from NBERT projects.

I. NBERT Online Platform

The following section provides an overview of the NBERT online platform.

C. Requirements and objectives

The project involves collating together all the information about the building relating to its geometric details, thermos-physical properties and energy systems design and publishing online in an informative way. This information will be required to compliment long-term data within the relational database. All these details are presented in an interactive, easy to use format that can be readily accessed by researchers developing building energy solutions or energy models of similar applications, educators and students that are looking for a source of data for project based learning or policy makers wanting to know more about validated solutions for passive robust retrofit of the existing building stock. Details of all instrumentation and energy systems are also provided to allow for development of energy modes by researchers. All instrument locations are included with unique identifiers that are linked to the database for data extraction. In addition to building data, all publications relating to the project are brought together and presented in the interactive portal.

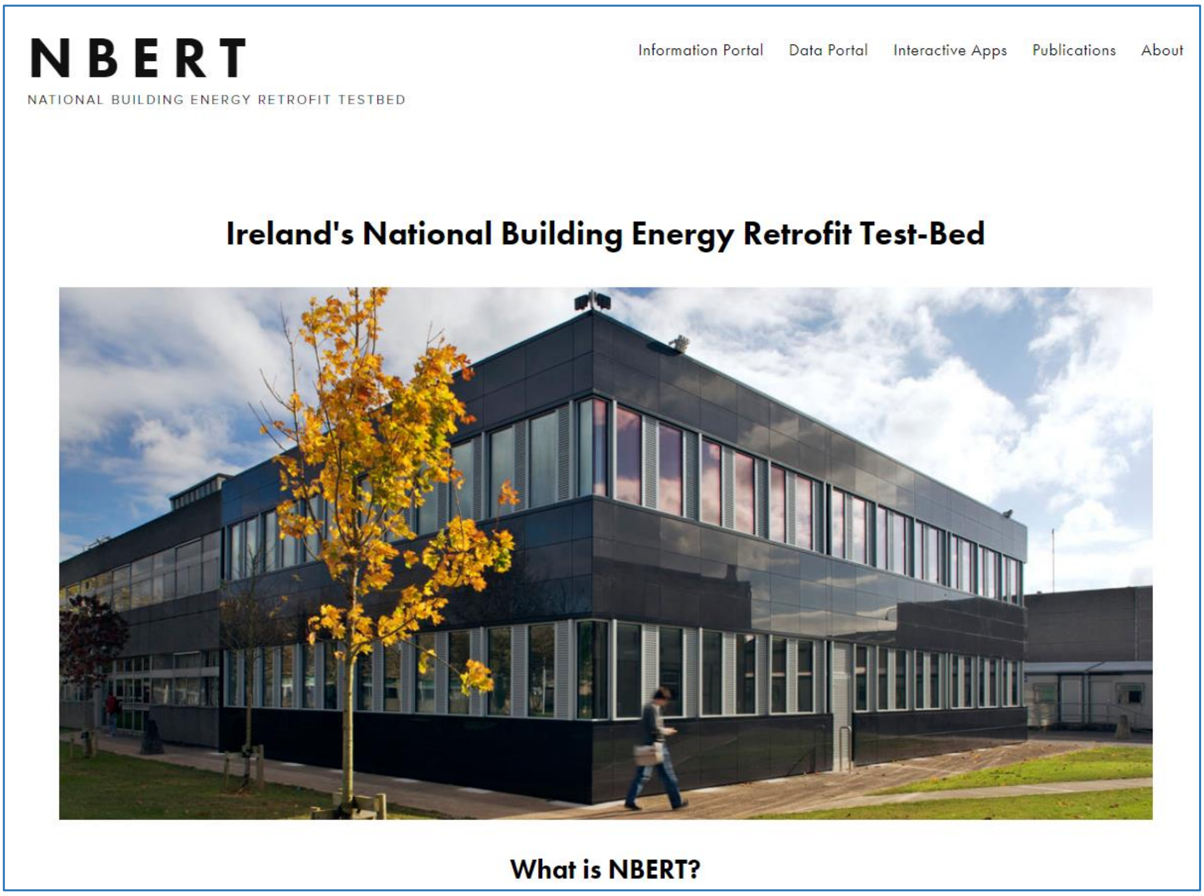

Figure 1.1: Screenshot of NBERT online platform's main page

The project objectives can be summarised as follow:

- Provide a publicly available source of empirical data use in the assessment of performance of energy and environmental building models
- Develop a template for the dissemination of well-documented information, data and knowledge related to the measured performance of a low energy retrofit ventilative cooling case study in the Irish climate.
- Provide a rich source of information for the undergraduate and postgraduate research projects in energy and the built environment for Ireland and further afield.
- Develop an online tool for the assessment of Irish climatic cooling potential of various ventilation strategies and building configurations that rely on untreated outdoor air for their source of cooling.
- Demonstrate the existing and future potential of ventilative cooling in Ireland

D. Online platform purpose

The purpose of the information portal is to develop a valuable set of information sources that provides public and researchers with information, tools and publications about the NBERT project.

Table 1.1: Main information on the NBERT online platform

Date of creation:	January – April 2018
Owners:	Cork Institute of Technology
Type of access:	Open source
Official Launch date:	September 2018
Creators and ongoing maintenance:	MeSSO Research (http://messo.cit.ie)
Available on:	Desktops, phones, laptops

E. Target audience

The target audience is mainly composed of researchers such as undergraduate or postgraduate students, educators, and of policy makers, which are interested in building properties, energy consumption, and internal environmental quality or want to know more about validated solutions for passive robust retrofit of the existing building stock. It is expected they will use the NBERT online platform in order not only to find information, tools and publications about the NBERT project, but also to test by themselves the different tools offered in the portal and compare the data obtained with other projects. Moreover, a publication page is available in order to give access to everyone to all the scientific papers, all the presentations and the articles relating to the project.

Table 1.2: Target audience and what we expect them to do

Target Audience	Where we expect them to go on the website
STUDENTS and TEACHERS	• Energy system/Building info/ environmental quality section • Data portal • Researcher section
POLICY MAKERS	• Factsheets • Public section
COMPANIES	• Contact us • Public section • Team

F. Structure of the NBERT Online Platform

1. Design

The online information portal is easy to use. Indeed, most of the time, three clicks are needed to access, from the main page, to any area of the information required by the user. The menu, which is located on the top right angle of the online portal, is also very simple: only four sections are described and the section titles are short. The entire design of the website is ergonomic and sober: three colours compose the information portal. Furthermore, the writing policy adopted is readable and sober. The information portal is split into a Summary section, which includes a number of factsheets and an overview of the NBERT project, and a Detailed section, which is intended for used by students and researchers as well as building professionals.

2. Site map

The following table summarises the site map. It covers the various different website pages and what information is available at those pages. The reader is advised to also peruse the website itself for further details about each different section. The flowchart in Figure 1.2 explains how the user can navigate through the various sections of the NBERT website.

Table 1.3: Site map of the NBERT online platform

Webpage	Details
Main	Includes summary information about NBERT, the Zero2020 project and the SEAI Funded portal and tools. It includes navigation options to other areas of the site such as the apps, the data and information portals as well as an activities feed that is linked to the NBERT blog.
Link:	https://www.nbert.xyz/main2
Information Portal	Access to the public and the researcher sections, as well as the contact us page. There are two factsheets available for download.
Link:	https://www.nbert.xyz/information-portal
Data Portal	The data portal is accessible from this page. This contains all datasets published to date for NBERT.
Link:	https://www.nbert.xyz/relational-database
Interactive Apps	Access to the VCPA tool and other interactive apps that will be made available in the future.
Link:	https://www.nbert.xyz/tools
Publications	Provides a repository of three different types of publications: *Scientific Articles* – High quality peer reviewed articles published in academic journals. *Presentations* – Presentations that have been delivered at various conferences, seminars and workshops relating to NBERT and zero2020. *Industry Articles* – Articles and pieces written in industry magazines The publications section is updated as new material is produced.
Link:	https://www.nbert.xyz/publications-new
Web Blog	Used to publish news and updates about anything related to NBERT.
Link:	https://www.nbert.xyz/nbert-blog
Contact us	NBERT building address, phone and an online contact form.
Link:	https://www.nbert.xyz/contact-us
Team	Gives some info on the team responsible for NBERT.
Link:	https://www.nbert.xyz/team
Building	Summary of zero2020 and NBERT in the context of the building. Ongoing Images of the project throughout its lifetime
Link:	https://www.nbert.xyz/building

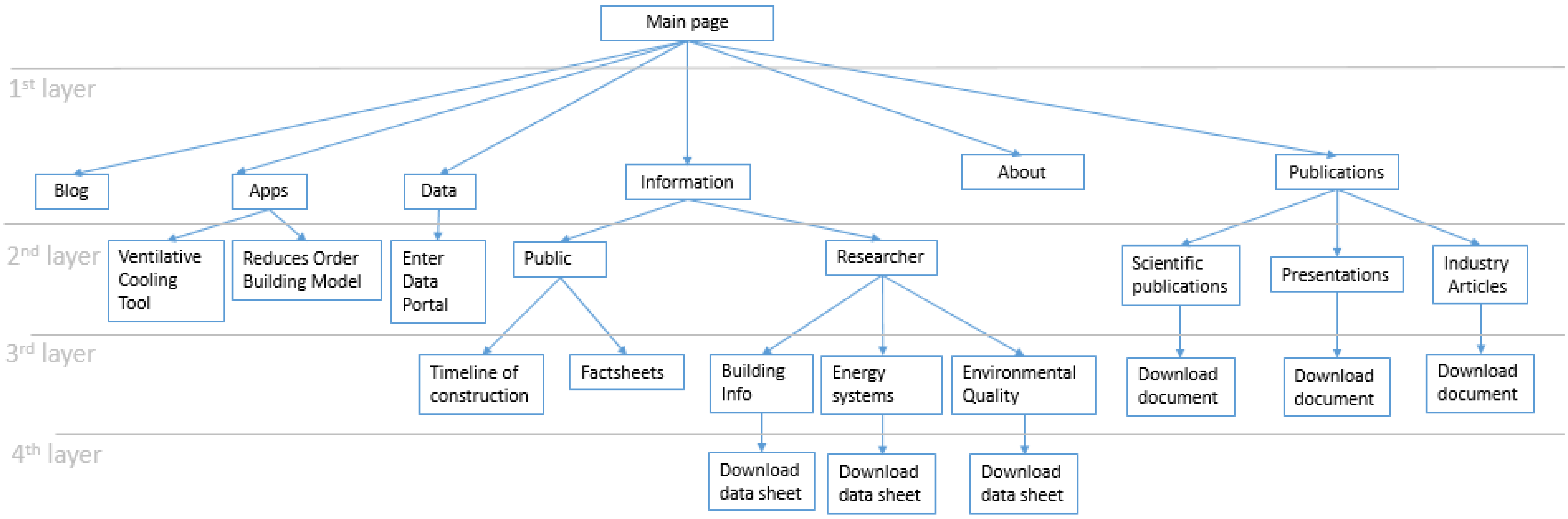

Figure 1.2: NBERT online portal flowchart

3. Scope of Functionality with the NBERT Online Platform

Table 1.5 outlines the various different functions available with the NBERT online platform while Table 1.6 summarises the type and format of information available on the portal.

Table 1.5: Different things that can be done with the NBERT online platform

Target Audience	What we expect them to do on the website
ARCHITECTS	• Download the information about the building and its thermophysical properties
STUDENTS and TEACHERS	• Compare data from an energy model with the performance data at NBERT • Investigate the cooling potential of NBERT under different climates • Gather data on internal air temperatures and on energy consumption • Analyse temperature and relative humidity data to evaluate the thermal comfort • Learn about Ventilative Cooling • Use the Ventilative Cooling tool • Be aware of the energy consumption of the building
POLICY MAKERS	• Understand how policy can be influenced by the NBERT initiative • Compare the energy consumption before and after
COMPANIES	• Contact us • Learn about the ZERO 2020 building • Compare the energy consumption before and after • Access the collaborators websites

Table 1.6: Type of information provided on the NBERT online portal

Type	Details
Building geometry and details	Online images with summary text and downloadable pdf drawings
Material Specs	Online overview with downloadable data sheet pdf documents
Airtightness data	Online details Configuration drawings
Natural ventilation system	
Thermal bridging	Online summary
PHPP / NEAP model results	Online summary of model outputs
Energy and environment systems	Online summary with downloadable schematic drawings, sizing details
Publications	All publications relating to the testbed research made available
Performance data	Dedicated section summarising the outcomes from long and short term monitoring campaigns with links to relevant data in the data portal
Timeline of construction	Details relating to the design and construction is presented

4. Number of minimum clicks before finding the information needed

The number of clicks a user needs to complete in order to access various sources of information is shown in Table 1.7. This demonstrates that within small amount of time users can get at detailed data and information, thereby reducing the risk of frustration or loss of attention.

Table 1.7: Number of minimum clicks before finding the information needed

What are you looking for?	Clicks from the main page
Access to the blog	1 click
Access the partners website	1 click
Contact Us	1 click
About the building	1 click
About the team	1 click
Access the scientific publications	2 clicks
Compare the performance before/after	2 clicks
Enter the data portal	2 clicks
Open the Ventilative Cooling tool	2 clicks
Open the reduced order building model	2 clicks
Access the presentations	2 clicks
Access the industry articles	2 clicks
Learn about the building properties	3 clicks
Learn about the energy systems	3 clicks
Learn about the environmental quality	3 clicks
Open the fact sheets	3 clicks
Download a paper	3 clicks
Timeline of construction	3 clicks
Download the plans and details of the building	4 clicks
Download material properties	4 clicks
More details about the heat pump/radiators/ air tightness (zip file)	4 clicks

This table allows the NBERT team to check if the NBERT online portal is easy to use or not. It also allows the team to see the changes that are to be made in the website. For example, 4 clicks to download a document may be too much and the user might be discourage to use this functionality. This table is a good starting point to improve future revisions of the NBERT online portal.

II. Interactive NBERT Information Portal

A. Overview

The “NBERT Information Portal” section of the website is an open source online web-based portal that allows researchers, students and policy makers to access data from a fully occupied nearly zero energy building (NZEB). The information portal contains two main different sections:

- Summary section - Download factsheets, datasheets from the NBERT building
- Detailed section - Learn about the building, the energy systems and indoor environment

B. How to use the information portal

1. Access and landing page

The NBERT information portal can be accessed on the www.nbert.xyz main page in the information portal section. From there, users have access to the NBERT information portal landing page as shown in Figure 2.1.

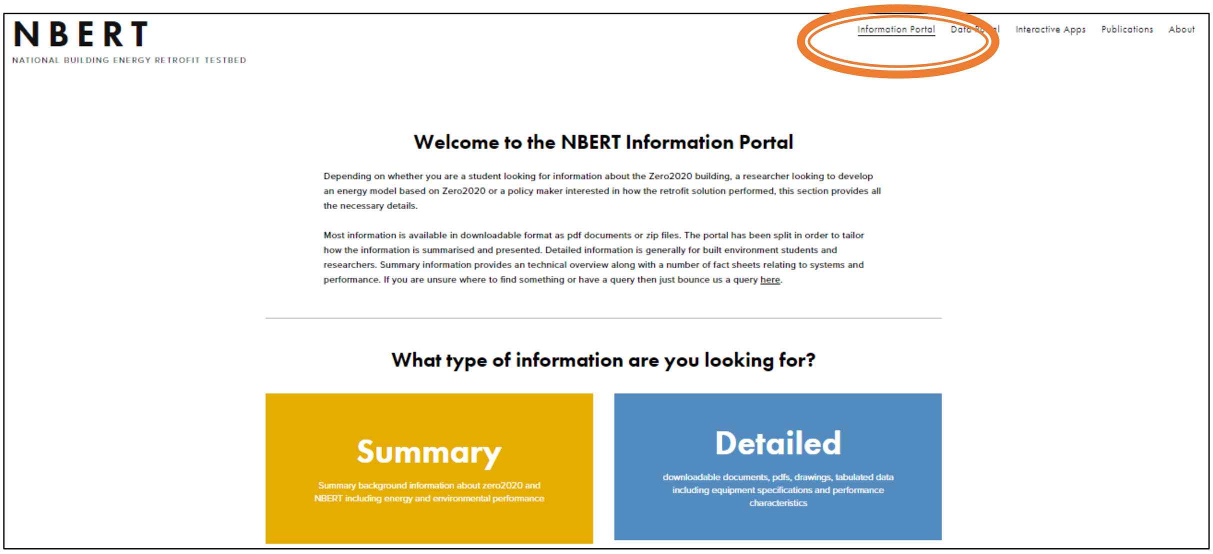

Figure 2.1: Screenshot of the main landing page for the information portal

2. About the information portal

As previously mentioned above, the information portal is divided in two sections: the first section is dedicated to non-experts as well as those looking for key facts and figures while the second one is more dedicated to researchers and students looking to interact with the information and use it for various purposes. Most information is available in downloadable format as pdf documents or zip files. Inside the summary section, users can find the information about the performance of the original 1974 pre retrofit building compared to the performance of the zero2020 building. Users can also see how NBERT came about thanks to the timeline of construction. Anyone visiting the public section of information portal can download three factsheets (see Figure 2.2 below).

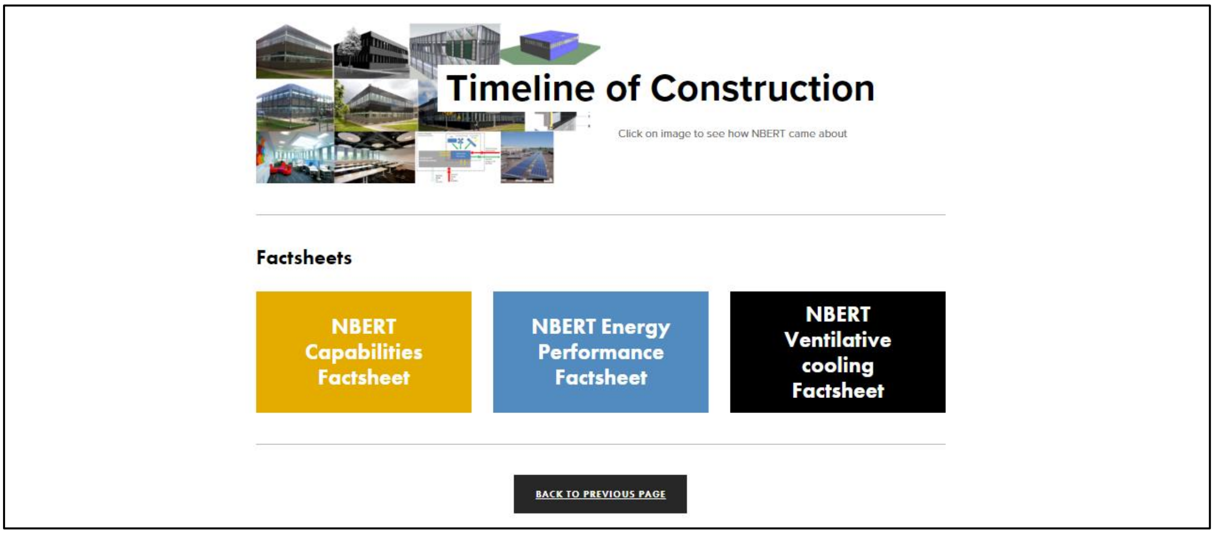

Figure 2.2: Screenshot of the timeline and downloadable factsheets

One factsheet is about the NBERT research and capabilities. It summarizes the different research projects, the infrastructural facilities, the NBERT team and key information about the testbed. The second factsheet is a 2 page summary of the NBERT zero2020 building retrofit and concept as well as the testbed. In this factsheet, the users can see the time-line, the key targets for public buildings to reduce their energy consumption, the performance of the building before (1974) and after (Zero2020) as well as other key stats and metrics. A final factsheet is a more detailed 12 page summary of the zero2020 building and the passive VC strategy installed in the building. It was developed separately under the IEA-EBC Annex 62 project on Ventilative Cooling. It contains a lot of valuable information about the design and performance of the zero2020 retrofit project. If users choose to visit the Detailed section, three other options are available: the building information section, the energy systems section, or the indoor environmental quality section (shown in Figure 2.3). At the bottom of every page, users can decide to go to the data portal to explore further long term measurement data for the building (see Section III below).

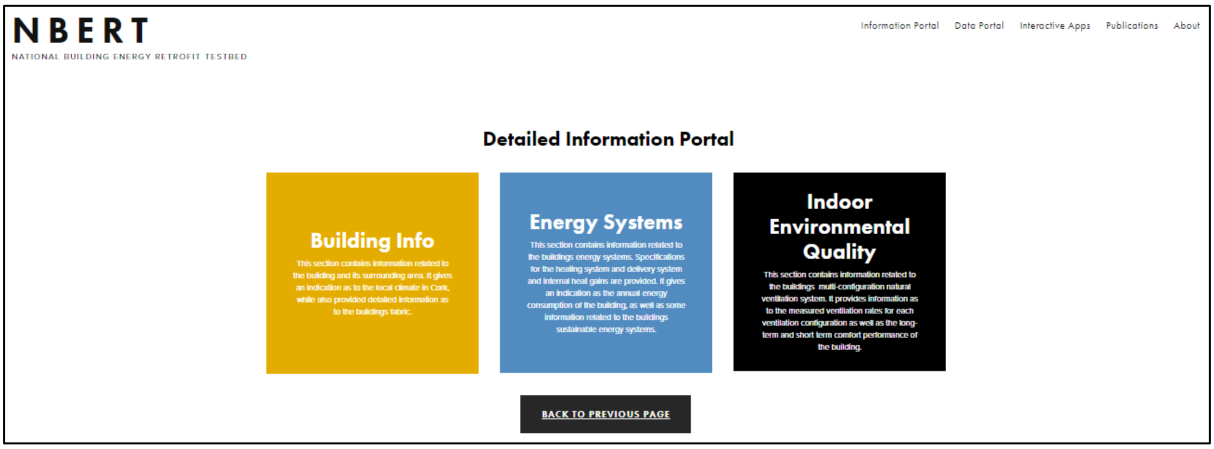

Figure 2.3: Screenshot of the Detailed Information section landing page

In the building information page, users can find information about the surrounding area and geometry of the building. The local climate, the thermophysical properties of the building elements including the fenestration are also explained. There are downloadable files for all information presented. In the energy systems page, the heating system, the internal heat gains and the micro grid system are briefly described. In order to have more information, users can download the data sheets. The energy performance is detailed and a graph shows the evolution of the annualised energy consumption in the Zero2020 building. In the indoor environmental quality section, information related to the buildings multi configuration natural ventilation system is depicted. It provides information as to the measured ventilation rates for each ventilation configuration as well as the long-term and short term comfort performance of the building.

III. Data Portal

A. Overview

The "NBERT Data Portal" is an open source online web-based portal that allows researchers and students to access data from a fully occupied nearly zero energy building (NZEB). The data portal contains four years of data from 2013-2016. There are three main data types:

- Weather data,
- Internal Environmental data,
- And energy data.

The NBERT data portal allows users to:

- View NBERT data in graphical and tabular forms
- Download data from the NBERT database
- Upload and compare their data to NBERT data

Table 3.1 explains the layout of the NBERT data portal. Each data source in Table 3.1 will be explained further in Section B.

Table 3.1: Layout of NBERT building internal instrument positions presented

Section	Details / Format
About	This section provides the user with information about how the portal is structured, how to use the data portal to access datasets and what analysis functionality is available. It is effectively an overview and user manual.
Energy	This section contains all measured energy performance data from the testbed for 2013 – 2016.
Internal Environment	This section contains all data from the wireless data logging system installed at NBERT. This covers parameters like air temperature from 2013-2016.
Weather	This covers weather data from the NBERT weather station. Parameters include ambient air temperature, ambient humidity, wind speed and direction, barometric pressure etc. from 2013-2016.

B. Data gathering systems and data gathered

The NBERT building has capabilities in monitoring and gathering internal and external parameters from both a typical building management system (BMS) a more detailed internal environmental monitoring system and an on-site weather station. There are three data gathering systems in the building:

- A Campbell Scientific Weather station
- A Hanwell Internal Environmental wireless monitoring system
- A Cylon data gathering system for the BMS data

The BMS system monitors and gathers data on internal air temperatures, energy consumption for general services, lighting, and the buildings air source heat pump. It also measures the position of actuators for the natural ventilation system in the building. Externally, NBERT has an on-site weather station located on top of the building. To create the dataset used in the online data portal data is gathered from the three main sources mentioned above where data is stored in a local hard drive. The local BMS system uses Cylons Unitron report software to log data related to the building and Unitron datalog manager software to select and download data. The Hanwell system uses Hanwell RadioLog software to view and download data from wireless data loggers. Data from the Campbell Scientific weather station is collected and appended in file locally using Loggernet software.

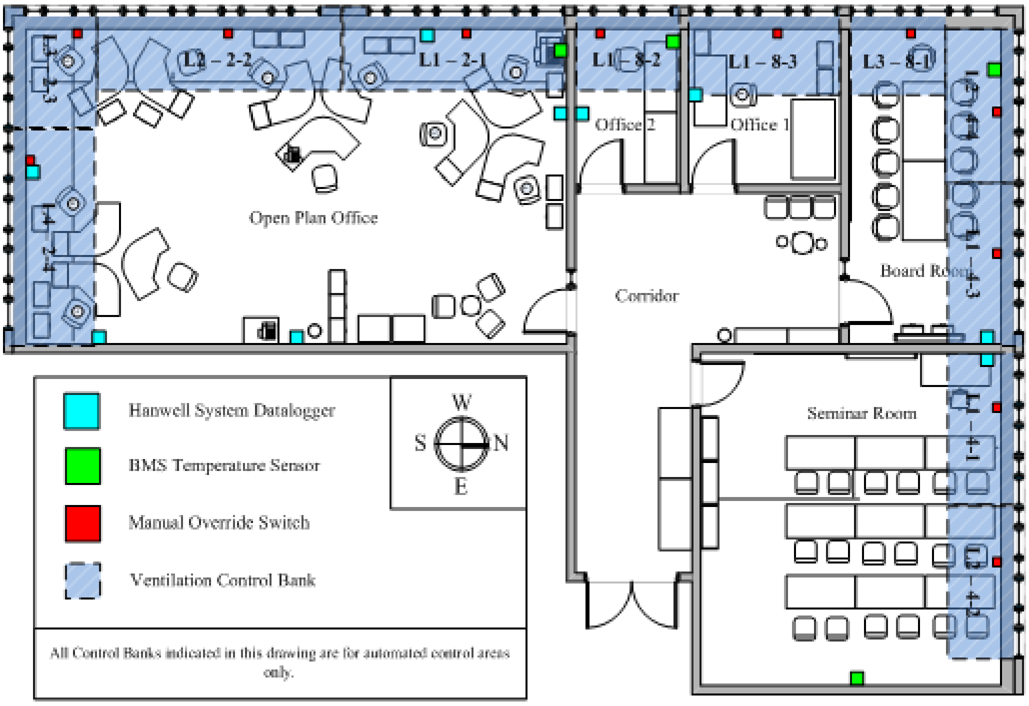

Figure 3.1: Layout of NBERT building internal instrument positions presented

The Unitron system stores files locally in the BMS computer which has all daily datalogs for each measured parameter. Figure 3.1 above shows the position of all internal sensors in the building, while tables 3.2 and 3.3 indicate the measurement accuracy for all internal and external sensors. The external weather stations is shown in Figure 3.2.

Table 3.2: Instrument accuracy and logging intervals for internal data logging systems

Parameter	Instrument/System	Specification information
Temperature	Hanwell 4002T	±0.1°C (-10°C to 40°C)
Humidity	Hanwell 4115RHT	±2% (0%–90%) ±3% (90%–100%)
CO_2	Hanwell Climabox 3	±50ppm (0 – 4000ppm)
Temperature	TE-RT, BMS	±0.2°C (-20°C to 60°C)
Energy	Socomec DIRIS A20	Class 0.5S, EN- IEC 62053-22
Ventilation Position	BACnet Windowmaster	(0 – 100%)

Table 3.3: Instrument accuracy and logging intervals for external weather station

Parameter	Instrument/System	Specification information
Temperature	HC2S3 Rotronic Hygroclip 2 probe	±0.1°C at 23°C
Humidity	HC2S3 Rotronic Hygroclip 2 probe	0.8%RH at 23°C
Air Pressure	Vaisala PTB101B	±0.5mb at 20°C
Solar Radiation	Campbell Sci SP1110 Pyranometer	±5% for 350–1100nm /linearity 1% dev
Wind Speed	Campbell Sci 05103 Vane Wind Monitor	±0.3 ms^{-1} or 1% of reading (0-100 ms^{-1})
Wind Direction	Campbell Sci 05103 Vane Wind Monitor	±5.0°
Daylight Levels	Skye SKS 1110 Pyranometer	0-5000W/m^2 / typ. <3% cal err
Rainfall	EML Aerodynamic rain gauge ARG100	0.2mm/tip

Figure 3.2: Picture of weather station located on the roof of the building

The weather data is stored in one file that is appended once the data logger is connected. All data collected for each individual dataset was collected using a 'read-bulk' function in RStudio. In order to get the data in a useful format each dataset required processing. After a process which wrangled and tidied the data from its raw form to usable form a certain amount of data is lost. Figure 3.3 below is a flowchart as to how data gets from a raw format to a clean and sorted format for use by the RShiny database. While data is available at a measurement resolution as low as one minute for certain instruments, it is expected that this type of data would only be needed on special request. For the purpose of this data portal data is presented at an hourly resolution. In its current format only a sample of the key sensors from particular monitoring systems are presented.

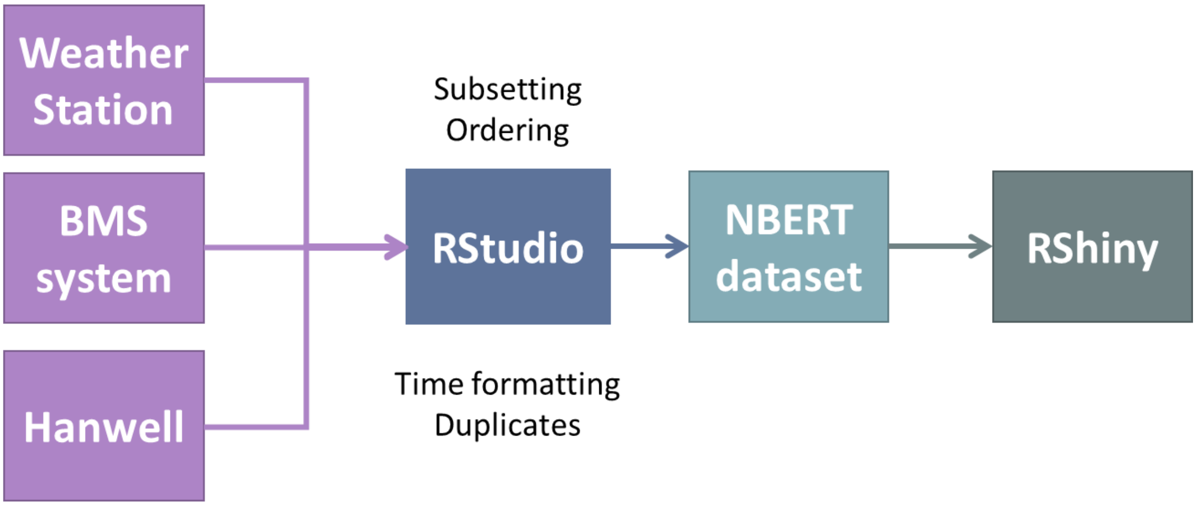

Figure 3.3: NBERT data collection, cleaning and transfer to RShiny web-platform

C. How to use the data portal

1. Access and Landing Page

The NBERT data portal can be accessed either directly from this link https://zero2020aod.shinyapps.io/App-1_new2/ but can accessed on the www.nbert.xyz main page in the data portal section also. When users initially reach the NBERT data portal webpage they are required to read and agree to the "Terms and Conditions" related to the data, as is shown in figures 3.4 and 3.5. Users will be unable to enter the data portal unless they click the "I Agree to the Terms and

Conditions" button located at the bottom of the modal pop up. Once the button is pressed, users have access to the NBERT data portal landing page as shown in Figure 3.6.

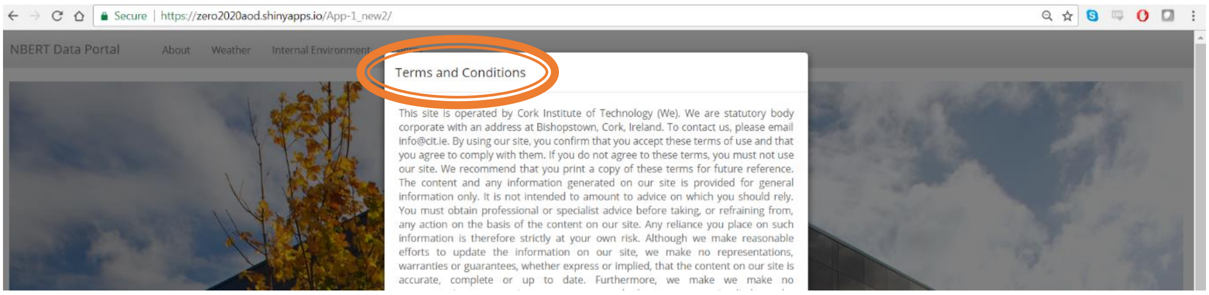

Figure 3.4: Screenshot of Terms and Conditions landing page modal pop up for data portal

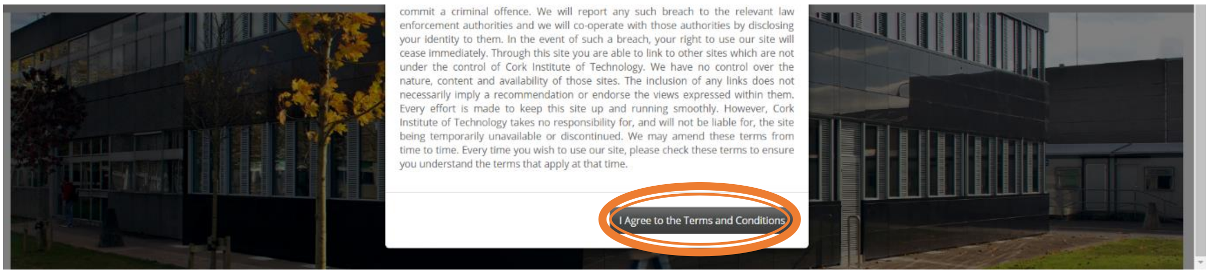

Figure 3.5: Screenshot of Modal pop up button for data portal

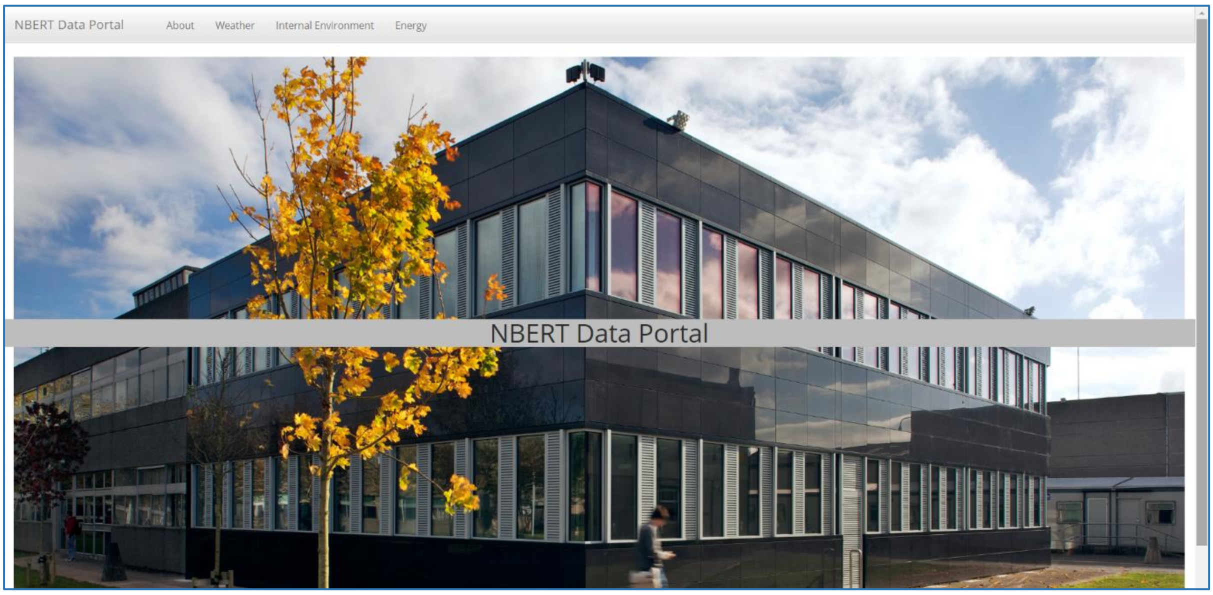

Figure 3.6: Screenshot of the main landing page for NBERT data portal

2. About the data portal

When on the main landing page users can easily decide what data they want to examine. Four page options are indicated in the main navigation bar (as shown in Figure 3.6):

- About
- Weather
- Internal Environment
- and Energy

Users are encouraged to look at the about tab initially before deciding to select the three data tabs. The "About" page (shown in Figure 3.7) gives data portal users insight into how the data was gathered, wrangled and tidied. A useful feature of this page is the data availability table located on the top right corner of the page as shown in Figure 3.8. It is inevitable that data will be lost in most data gathering systems. To guarantee the quality of the data gathered some data is omitted for various reasons, one of which is system downtime. Using the data availability table user must: 1) select the year the want to analyse, 2) select the dataset they want to analyse. Once this is done users will be able to see the percentage of a dataset that is available in a given year as is shown in Figure 3.9.

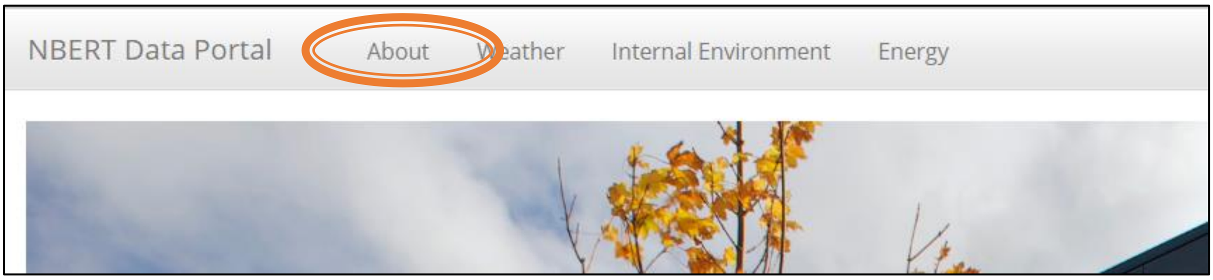

Figure 3.7: Screenshot of Navigation bar options

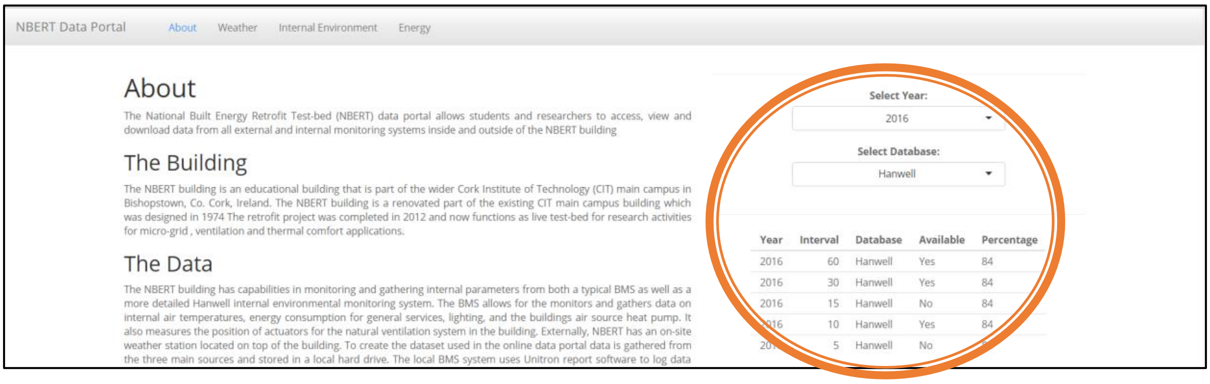

Figure 3.8: Screenshot of About Page with description and data availability tab

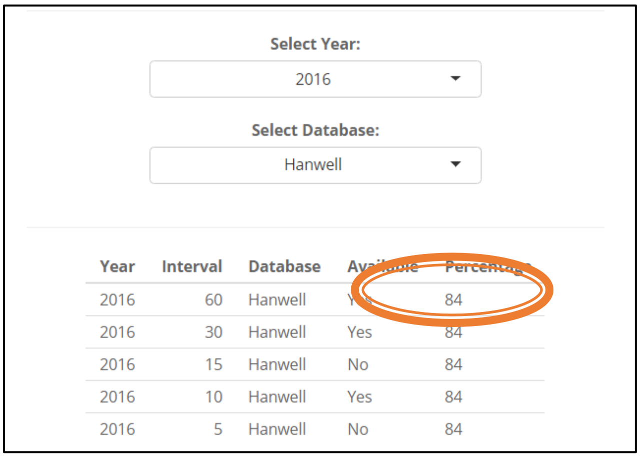

Figure 3.9: Screenshot of Data availability table for each year and database

3. Data selection and download

On either of the data pages (Weather, Internal Environment, and Energy) users are able to select one or multiple variables or sensors that they want to investigate. Using the common sidebar layout to all data pages users can:

a. Select a sensor,
b. Select a start and end date for the data, and
c. Isolate the hours of the day they want to investigate using the "Hour of Day" slider.

The only exception to this common sidebar is for users using the "Energy" data page. When users are using this page they are initially given an option of a "Monthly" or "Hourly" analysis. Following this they can select and hourly analysis to get the sidebar shown in Figure 3.10 or a monthly analysis to get the sidebar shown in Figure 3.11.

All data pages contain the following three tab options (as shown on the Weather data page):

a. An "Overview" tab
b. A "Data" tab
c. A "Visualise and compare" tab

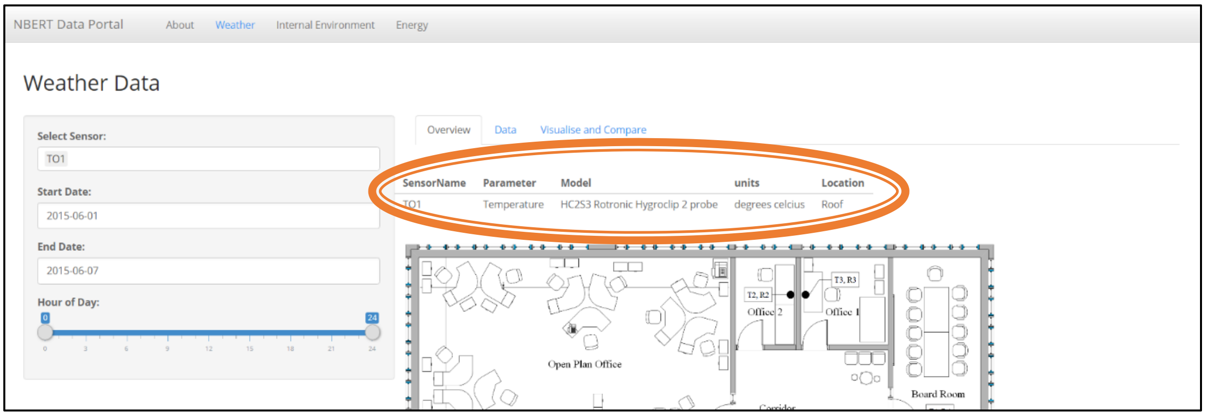

Figure 3.10: Screenshot of Weather data page showing the sidebar and overview tab

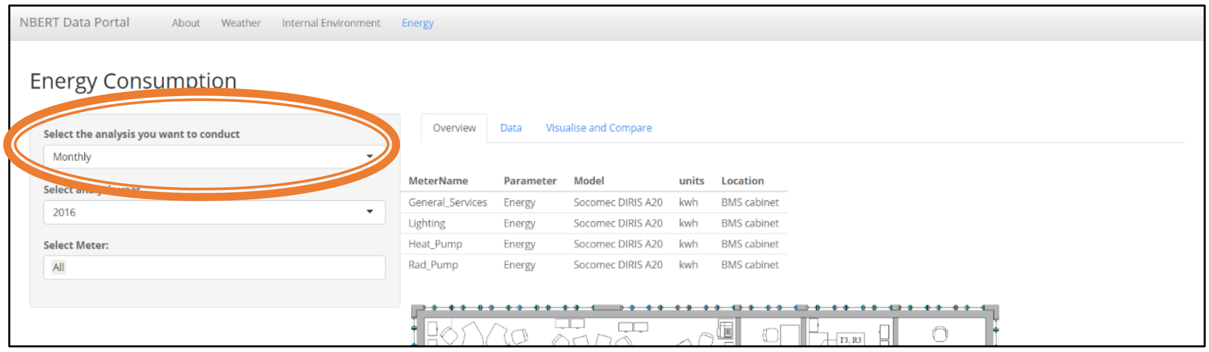

Figure 3.11: Screenshot of Energy data page showing the monthly and hourly analysis option in the sidebar

The “Overview” tab gives users insight into the location, sensor model, and units used for any sensor or meter selected in the “Select Sensor” input. As users select multiple sensors, multiple variables will appear in the sensor description table. For internal parameters a map is provided to give users more detailed information. The “Data” tab (as shown in Figure 3.12 below) shows users the data they have selected based on the sidebar of any data page. It is at this point that data can be downloaded, copied or printed using the buttons shown at the top of the data table in Figure 3.12. The data table that is made is also searchable using the search bar.

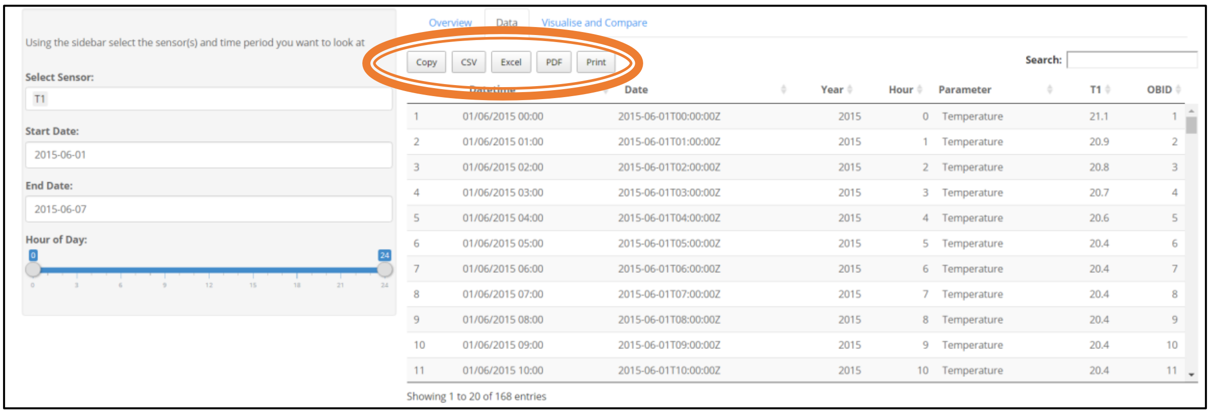

Figure 3.12: Screenshot of Tabulated data tab with download functionality

4. Visualise and compare

In the “Visualise and Compare” tab of each data page, data that has been selected from the NBERT database is visualised graphically with plotly graphics (https://plot.ly/). As is shown in Figures 3.13 – 3.15 below, plotly graphics are useful as they allow users to zoom into portions of the data selected, for a given time period. This can allow users to select a week, a month or a year while allowing them to also investigate daily or hourly trends easily. The two other main functions in this tab are: the data upload functions and the basic statistical summary section. The stat summary section below the plotly graph gives users basic information about the data they select like: the mean, the median, the min and the max value of the data they select.

Another useful feature of this tab is the ability for users to upload their own data in “.csv” format and compare it to the NBERT dataset. Users simply browse their computer for a file and when the upload is complete users can select the variables they want from their data and compare them to the NBERT dataset variables, as is shown in Figure 3.16 and 3.17 below. Once a variable is selected from the user defined file, a unique stat summary is also presented for the user defined variables that have been selected. The main consideration for users when uploading data is to consider the format it is in. Two formatting measures are important for optimal functionality when using the compare function:

1. Make sure your dataset has the variables presented column-wise with a header or name for each variable you expect to compare with the NBERT data
2. Ensure the length of your data is the correct length. For example if you are plotting for a week at hourly intervals you will have 1 row for a header and 168 observations. For the monthly comparison you will have 12 observations

To guarantee data is of the correct length please examine the length of the data in the “Data” tab of any data page. Section D below gives examples of how to use the upload data function in the NBERT data portal.

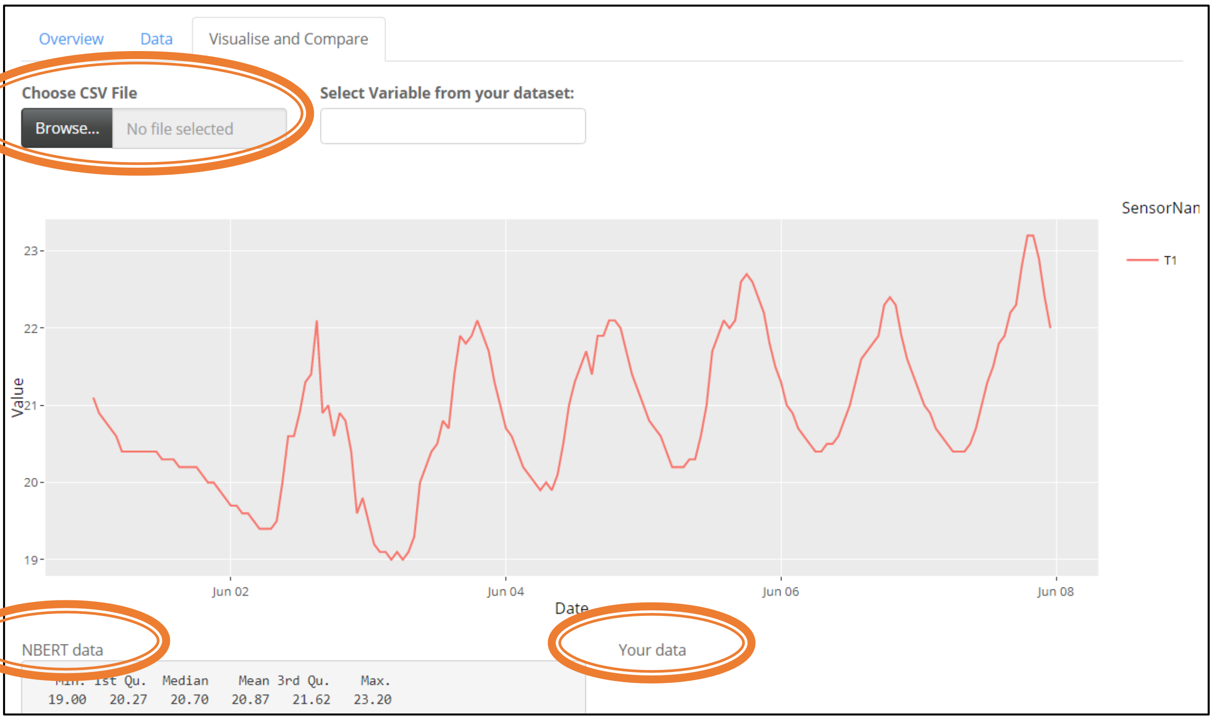

Figure 3.13: Screenshot of visualise and compare tab for the Internal Environmental data page.

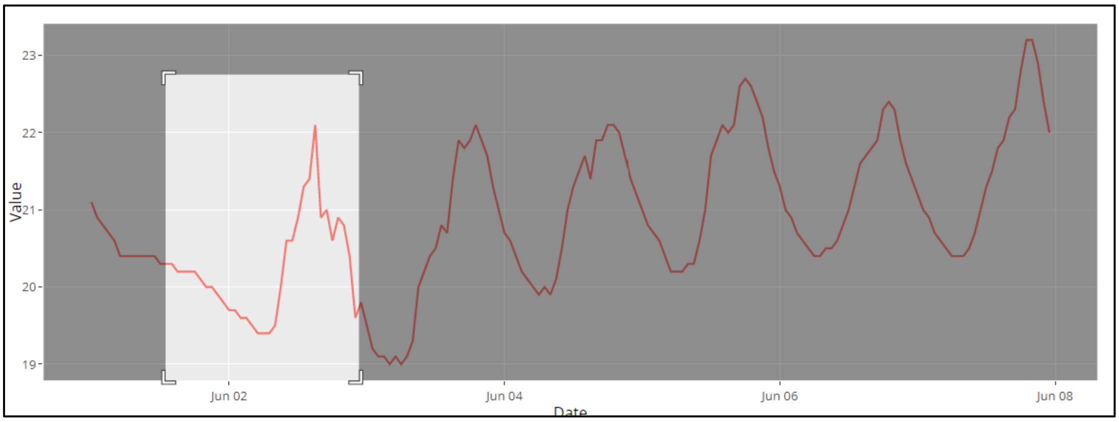

Figure 3.14: Screenshot of data selection with plotly graphics

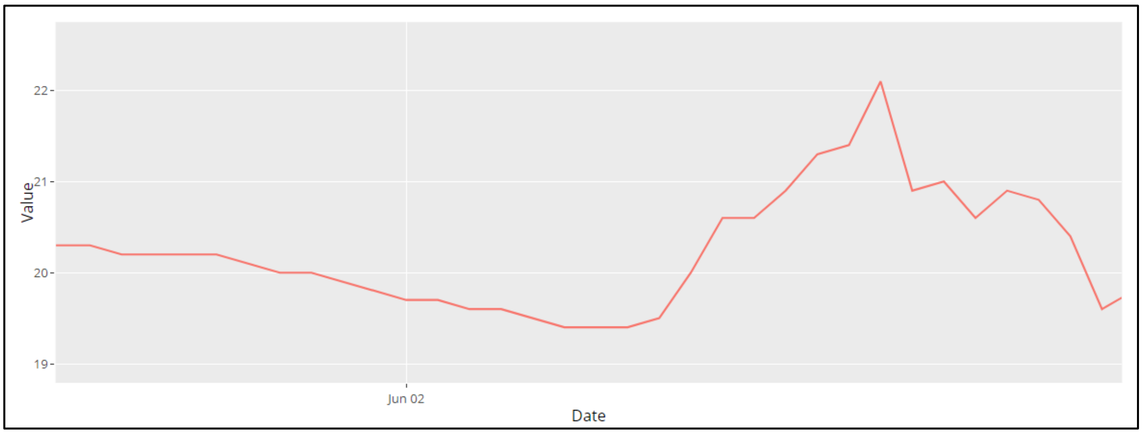

Figure 3.15: Screenshot of the resulting graph from plotly data selection

D. Compare function demonstration

In this section the data upload and compare functionality within the data portal will be demonstrated using data generated from a TRNSYS model and a PHPP model. Once you have uploaded your data from your computer and you data is in the correct format you can select variables easily. In Figure 3.16 you can see what the data would look like once it is uploaded to the NBERT data portal on the Internal Environmental data page.

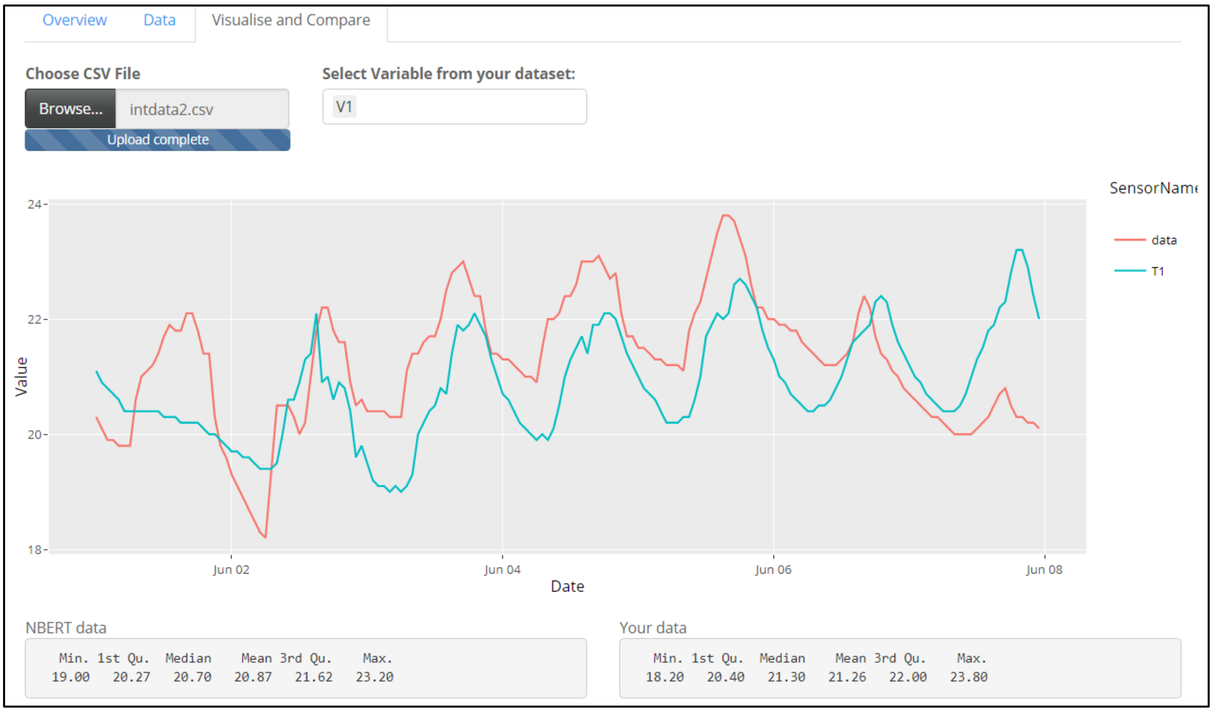

Figure 3.16: Screenshot of TRNSYS model outputs for a week compared to NBERT data for one week

In Figure 3.17 below data generated from a PHPP model of the zero2020 was uploaded on the Energy Consumption data page. To plot the bar chart the monthly option and the heat pump meter was selected. The year of data that was selected below was for 2016.

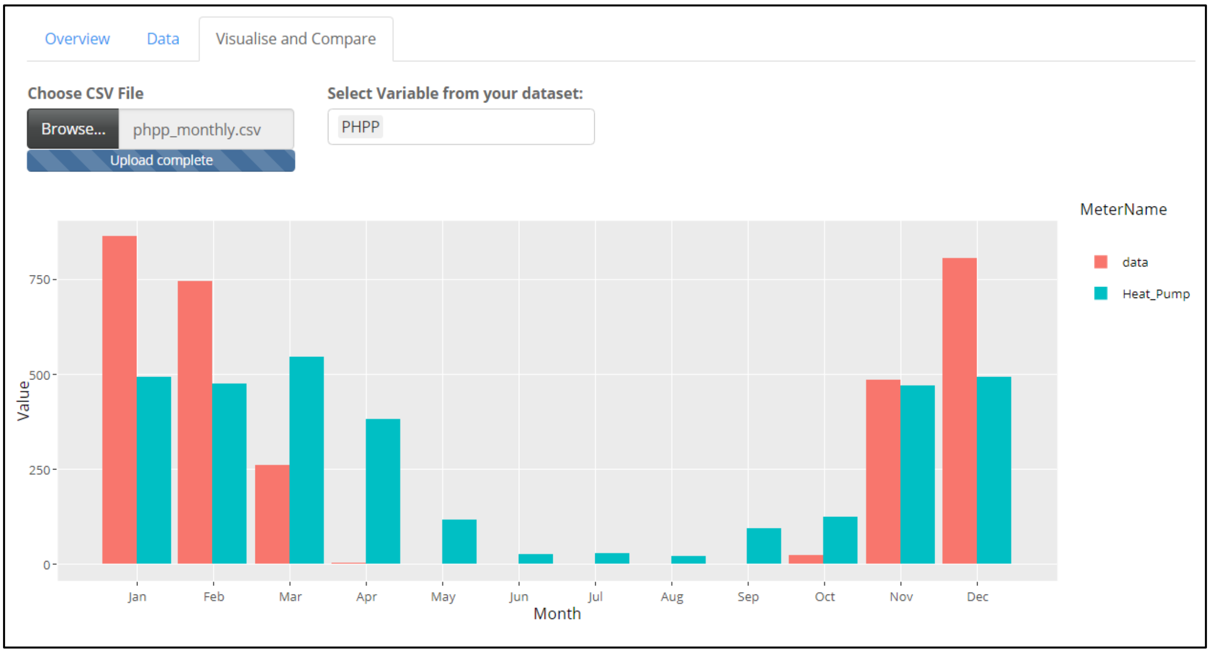

Figure 3.17: Screenshot of monthly PHPP model comparison with monthly NBERT heat pump data

E. Future functionality

Given its web-based platform and current structure, it is expected that the NBERT data portal could be easily expanded in future to include multiple additional functionalities particularly in the area of engineering education. It is envisaged that an “Education and Exploration” page could be developed that would incorporate learning in areas such as:

- Thermal comfort and comfort standards
- Indoor air quality and IAQ standards
- Ventilation system modelling
- Heating degree day analysis
- Statistical modelling of large datasets
- Basic building energy consumption modelling and theory

This page would have two main functions:

1. **Learning** – this section would consist of multiple learning packages that would teach students about a topic which would include an interactive quiz or questionnaire to support the learning around the topic
2. **Exploration** – following directed learning about a topic, students will be directed to analysis page related to that topic where they can analyse the relevant NBERT dataset by applying the theory they have learned. Each exploration page will consist of a separate RShiny application. The code for all these specific analysis tools will be shown for students to see as they are performing an analysis.

IV. Interactive Apps

A. Overview

Interactive engineering design and analysis applications also form part of the new online platform. While these are intended to perform a more standalone function than the information and data portal they still form part of the overall portal and can be used either for education purposes as integrated learning delivery tools for energy modelling and energy analysis modules or as early design stage analysis tools for professionals. They will be accessible from the main NBERT platform at https://www.nbert.xyz/tools/. These will generally be online modelling and simulation based applications that can be used to explore parametric analysis of different building related energy systems. The first of these applications that is now available is the Ventilative Cooling Potential Analysis (VCPA) Tool. The VCPA tool was also developed in RShiny. Figure 4.1 below shows how to access the VCPA tool.

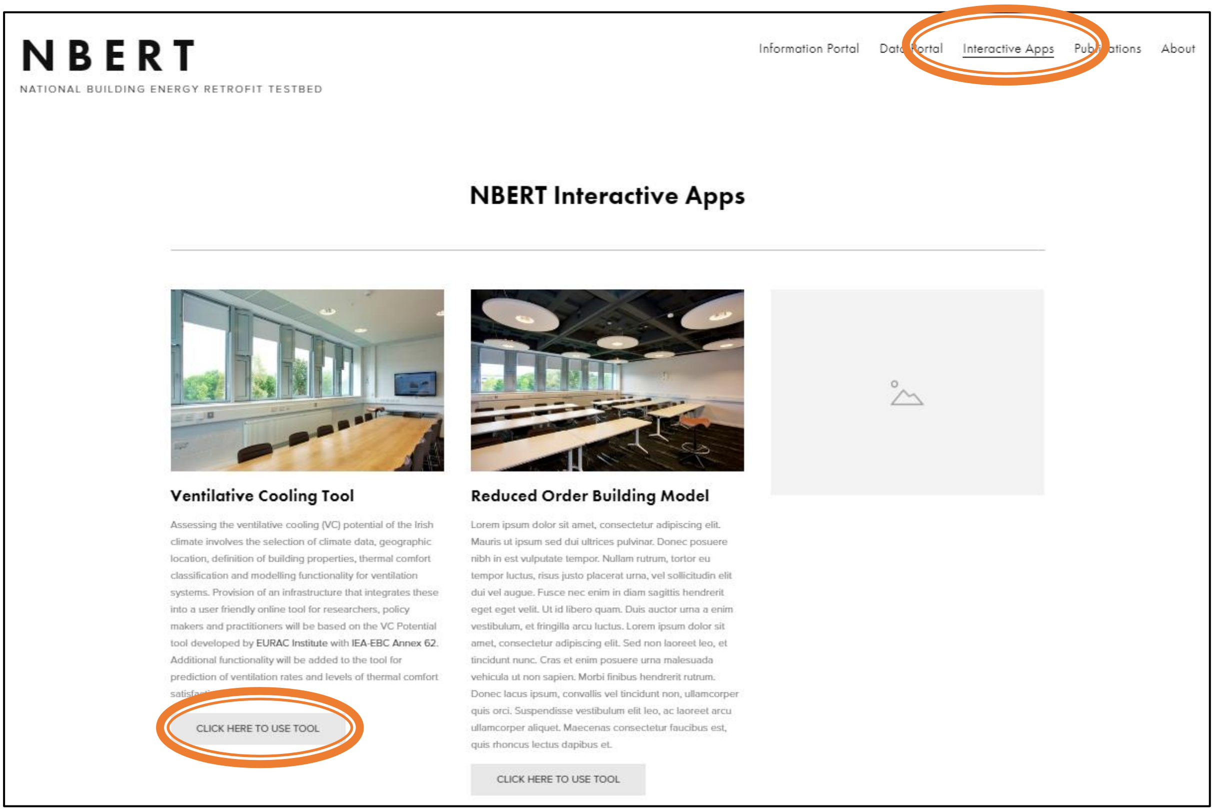

Figure 4.1: Screenshot of the NBERT Interactive Apps landing page

To use the interactive apps, users have to click on the buttons “Click here to use tool”.

B. The Ventilative Cooling Potential Analysis (VCPA) Tool

A cooling potential exists in the external ambient air when it is sufficiently below the indoor air temperature that is identified as being the acceptable upper thermal comfort temperature limit for building occupants. In other words, when the ambient air is sufficiently cooler than the target indoor air temperature, and there is a cooling demand within a building, the ambient air can be used to directly cool the interior space at no additional energy cost (or that of the fan driven enhanced airflow rate above the minimum for IAQ when mechanical ventilation is adopted). The extent of cooling available will depend on the external ambient temperature, the range of supply airflow rates possible using the ventilation strategy for the building, and the magnitude of the heat requiring removal to maintain the indoor air temperature within the thermal comfort range. IEA-EBC Annex 62 State of the Art Review [24] report recently defined Ventilative Cooling (VC) as:

The application of ventilation flow rates to reduce the cooling loads in buildings. VC utilizes the cooling and thermal perception potential of outdoor air. The air driving force can be natural, mechanical or a combination.

It is important in the early design stages of low energy buildings to identify the suitability of a particular climate and building combination to use natural or mechanical ventilation for cooling purposes. This is of particular importance given the increased sensitivity of low energy, well insulated, airtight spaces to variations in the heat balance of the indoor environment. Ensuring there is sufficient potential for free cooling in the climate will assist in determining the most suitable cooling strategies during the early stage design and selection of VC systems. The extent to which ventilation can provide the required cooling is based on the available ventilation rate above the nominal IAQ value and the available temperature difference between indoor and outdoor conditions. There are two stages to the VCPA simulation tool; the cooling potential of the building/climate combination and the ventilation opening cooling performance.

To estimate the climate cooling potential for a building the general steps are:

1. Submit thermal characteristics in the building data section
2. Submit building geometry in the building data section
3. Submit additional details about the usage of the building in the building data section
4. Select daily occupancy profile include lunch break
5. Select building location and climate horizon
6. Assess simulation outputs from cooling potential analysis

To assess the cooling performance of a ventilation opening the general steps are:

1. Define physical dimensioning details about the opening
2. Define fluid/structure interaction data for the opening (discharge co-efficient, free are ratio etc)

3. Define the proposed number of openings

4. Assess simulation outputs from the ventilation opening performance analysis

The VCPA tool is based on the theoretical method originally proposed by Axely and Emmerich [25] and further developed within IEA-EBC Annex 62 by Eurac Institute. More details regarding the background to climate cooling potential can be found here . A paper summarising the development of the method that the tool uses is here [26] and further information about the International Energy Agency Project where the method was initially developed can be found here. The version of the tool contained in the suite of NBERT apps is specific to Ireland with pre-loaded weather files and building typologies based on the Irish climate and building industry. Table 4.1 shows which annual hourly weather files are currently available within the VCPA tool. All weather files are TMY3 format. More locations and horizons will be added in future revisions of the tool.

Table 4.1: Climate locations and horizons currently available within the tool

Location	Horizons available	IPCC Emissions scenarios
Athlone	Present, 2030, 2050	A1B
Cork	Present, 2030, 2050	A1B
Donegal	Present, 2030, 2050	A1B
Dublin	Present, 2030, 2050	A1B
Belfast	Present, 2030, 2050	A1B

The VCPA tool is made up of a number of separate sections that the user can work through and use in their analysis. There are four sections; About, Building Data, Cooling potential and Ventilation Performance. The 'About' tab provides a brief introduction and overview to the tool. The first tab where information must be provided is the building data section, shown in Figure 4.2.

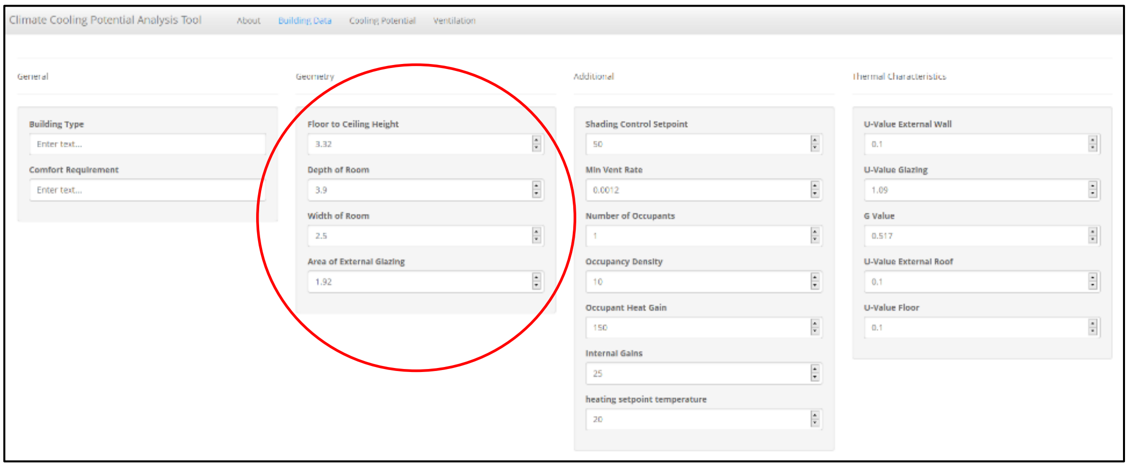

Figure 4.2: Example of model inputs required from the user (i.e. building zone geometry shown circled in red).

Here, the user inputs all the required information necessary to estimate the number of useful cooling hours from direct ventilation designs a particular climate and building configuration will have. Table 4.2

summarises what parameters are required for the analysis. Default values are shown for information purposes although these are all user defined within the tool.

Table 4.2: Summary of Building data required for estimation of useful cooling hours

Input Parameter	**Units**	**Default Value**
General		
Building Type	(-)	Open Plan Office
Comfort Category	(-)	III
Geometry		
Floor to ceiling height	(m)	3.3
Depth of room	(m)	3.9
Width of room	(m)	2.5
Area of external glazing	(m^2)	1.9
Thermal Characteristics		
U-Value External Wall	(W/m^2K)	0.21
U-Value Glazing	(W/m^2K)	1.8
G-Value Glazing	(-)	0.6
U-Value External Roof	(W/m^2K)	0.16
U-Value Floor	(W/m^2K)	0.16
Additional		
Shading control set point	(W)	80
Minimum Ventilation Rate	(l/s/p)	12
Number of Occupants	(QTY)	1
Occupant Density	(m^2/p)	10
Occupant Sensible heat Gain	(W/p)	150
Internal heat gain	(W/m^2)	25
Heating set point temperature	(°C)	20

Having defined the input parameters in the Building Data tab the user then defines additional information in the Cooling Potential tab that will influence the potential for useful cooling from the outside air. The occupancy hours and climate are selected from drop down menus as shown in Figure 4.3 below. Once these have been selected the tool produces a monthly breakdown of cooling potential categorised down as shown in Table 4.3. The data in Table 4.3 is presented in both number of annual occupied hours and percentage of total annual occupied hours. It is important to look at this data in the context of useful cooling hours available from the external ambient conditions for the particular building being assessed. The analysis highlights the potential for cooling from ambient air without the need for any mechanical assistance. The method uses an hourly heat balance approach to estimate the mass flowrate required to ensure the desired indoor air temperature is maintained given the net incoming and outgoing heat gains to the space.

Table 4.3: Summary of different states for VC

Output	**State**	**Description**
No VC Required	Heating is needed	Even with minimum flowrate for IAQ heating still required to maintain temperatures above lower thermal comfort limit*
Minimum Required ACR for IAQ	Cooling is needed	Minimum flowrate for IAQ sufficient for cooling purposes to maintain temperatures below upper thermal comfort limit*
Enhanced VC ACR Required	Cooling is needed	A flowrate above minimum for IAQ needed to maintain temperatures below upper thermal comfort limit*
No VC Possible	Cooling is needed	The external ambient air temperature exceeds the upper thermal comfort limit*

* The upper thermal comfort limit includes a 3K offset below the value defined by the adaptive thermal comfort model in EN15251. This is based on the assumption that no valuable cooling can take place with a temperature difference of less than 3K across the ventilation opening.

When the flowrate needed to maintain this target air temperature is greater than that proposed for Indoor Air Quality (IAQ) purposes then an enhanced VC airflow rate is needed. The analysis provides these flow rates as its output and assumes they can be delivered by the ventilation system. The useful cooling hours is based on the capacity to provide the flowrate being available and only restricts cooling when the external air temperature is greater than the upper thermal comfort limit (including an offset restricting cooling when the ambient air temperature is within 3K of the indoor air temperature). Figure 4.3 below presents a typical monthly breakdown of cooling potential for a given building and climate scenario.

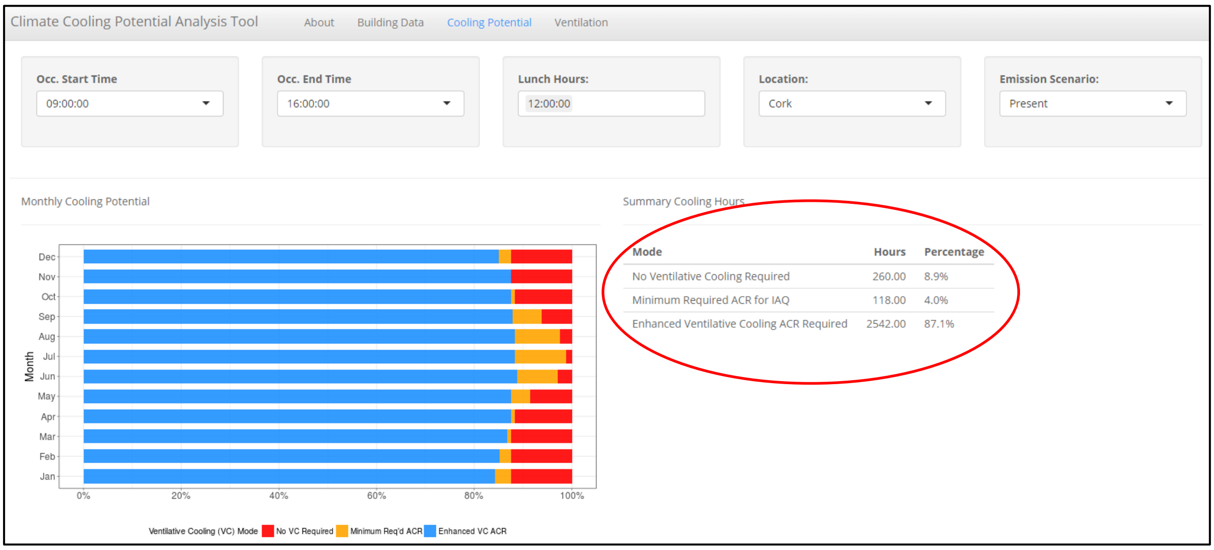

Figure 4.3: VCPA cooling potential interface. Percentage breakdown of monthly hours for various cooling modes plotted as a simulation output. Tabulated breakdown (Table 4.3), shown circled in red

The tool allows users to assess the effects different building characteristics, usage patterns and climates have on the potential for VC from the ambient air. The airflow rate can be provided either mechanically or naturally depending on the system design. Once the cooling potential has been assessed the VCPA tool allows capacity sizing of the ventilation system to deliver the required airflow rates. This part of the VCPA tool estimates the hourly airflow rate for the opening defined within the tool using the chosen weather data and the opening details. It uses a method defined by Warren and Perkins [ref]. Currently the tool includes only single sided ventilation openings. Cross flow ventilation and mechanical ventilation will be added in later revisions. Once the tool has estimated the hourly airflow rates from the ventilation opening it compares this to the required airflow rates from the cooling potential simulation (the cooling potential simulation calculates an hourly airflow rate based on the upper thermal comfort limit for indoor air temperature being satisfactorily maintained). The percentage of hours in each month where the opening cannot meet the required airflow rate to maintain the indoor air temperature below the upper thermal comfort limit is presented as a simulation output. This allows the user to determine the physical dimensioning of an opening in a building zone that is needed to provide the useful VC defined in the cooling section of the tool.

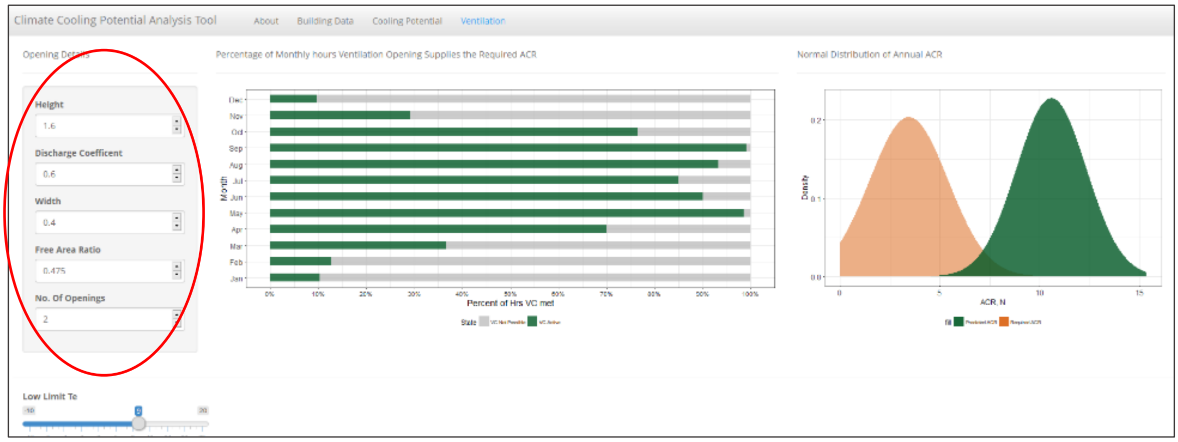

Figure 4.4: Example of model outputs that the student will interrogate and provide a summary of in their assessment. Parametric analysis is available using the panel circled in red.

It is planned that the tool will be used in an educational capacity primarily although professionals will also benefit from early stage analysis of building/climate combination assessments. For a built environment student using the tool, knowledge must be developed around each input parameter and why it has an influence on the potential for the climate to provide cooling to the building. This parameter set can be used as a training palette on building energy modules. As a learning assessment or example, the student can use the information portal discussed earlier to obtain all information necessary to complete a climate cooling potential analysis for NBERT. This can be completed in class as a learning example. Once the building and climate details have been uploaded and the cooling potential analysis has been completed the student then investigates how different types of ventilation strategy and ventilation opening perform when compared with the required ventilation rates for the building, calculated as part of the cooling assessment process. The VCPA tool greatly enhances the student learning experience. Often when energy analysis and design assessments are carried out it is difficult and time consuming for the student to undertake sensitivity analysis of various model inputs and design characteristics that might influence overall performance. A resource such as the VCPA tool, coupled with the NBERT information portal, provides an integrated platform to rapidly assess the effects of different variable values on system performance. This is the key strength of the tool and identifying how different characteristics influence performance facilitates a deeper insight into the design of direct VC solutions in low energy buildings. An attempt to develop this type of analysis from first principles within a module would be prohibitively time consuming. Students can automatically add results from their current analysis to a simulation outputs data frame and continue with new parameter values thereby building up a repository of performance values for different configurations for a statistical study.

V. Initial Insights & Future Work for the NBERT Platform

While the introduction of the new cross module online data platform is still in its infancy there are already a number of key insights that are worthy of mention. These are summarised below along with key developments that are already identified for future revisions of the learning platform.

C. Initial Insights

- RStudio and RShiny are very well adapted to the development of online engineering education apps. Simple design and analysis tools could be developed quite easily directly by undergraduate students or more in-depth version by postgraduates and lecturers. The RStudio suite is also fully open source making it license free and fully accessible.
- It is possible to develop a full online information rich suite without specific expertise in standard coding languages. No HTML or JavaScript was required to develop all aspects of the NBERT portal.
- It is possible to provide a fully open source information set for use by any university in the world. The NBERT portal will be available to any lecturer or educator interested in built environment topics and the development of energy, thermal comfort or internal environment models as well as specific applications like the VCPA tool.
- The online platform will act as a source of information for researchers to develop and calibrate models.

D. Future Work

The platform is now in its beta testing phase and it will be formally launched in September 2018. Following initial testing a number of future work items have been identified. These include:

- Development of an online sensitivity analysis function within the VCPA tool (December 2018)
- Development of an online cooling performance challenge for students with student comparisons of proposals. (September 2018)
- Part L building regulations benchmarking of NBERT and uploaded data within the data portal
- Heating degree days tool within data portal (September 2018)
- New interactive apps for building energy modelling, HVAC systems analysis and cleanroom ventilation systems design. (mid 2019)

VI. Demonstration of the VCPA tool: Irelands climate Cooling Potential

In order to demonstrate the use of the VCPA approach an investigation into Irelands climate cooling potential has been completed. The cooling potential of Ireland has been assessed about two pivoting axes; office building archetypes typical of Ireland and climates typical of Ireland. To test the sensitivity of useful cooling hours to climate, five geographical locations are included as outlined in Table 4.1. To test the sensitivity of useful cooling hours to building type, 4 different building configurations have been chosen. As there are thousands of different possible configurations of building and climate given the amount of input parameters required in the VCPA tool, only the thermophysical properties were adjusted to test how prohibitive the fabric of the building is to unlocking cooling potential for passive VC solutions. Table 6.1 outlines the 3 different building scenarios.

A. Simulation Conditions

Table 6.1: Building configuration scenarios

Input Parameter	Units	S1	S2	S3	S4
General					
Name		PartL2008	PartL2017ret	PartL2017new	NBERT
Building Type	(-)	Office	Office	Office	Office
Comfort Category	(-)	III	III	III	III
Geometry					
Floor to ceiling height	(m)	3.0	3.0	3.0	3.0
Depth of room	(m)	8.0	8.0	8.0	8.0
Width of room	(m)	12.0	12.0	12.0	12.0
Area of external glazing	(m^2)	14.4	14.4	14.4	14.4
Thermal Characteristics					
U-Value External Wall	(W/m^2K)	0.60	0.35	0.21	0.10
U-Value Glazing	(W/m^2K)	2.20	1.60	1.60	1.10
G-Value Glazing	(-)	0.80	0.40	0.70	0.57
U-Value External Roof	(W/m^2K)	0.35	0.25	0.20	0.10
U-Value Floor	(W/m^2K)	0.60	0.45	0.21	0.21
Additional					
Shading control set point	(W)	80	80	80	80
Minimum Ventilation Rate	(l/s/p)	12	12	12	12
Number of Occupants	(QTY)	-	-	-	-
Occupant Density	(m^2/p)	10	10	10	10
Occupant Sensible heat Gain	(W/p)	90	90	90	90
Internal heat gain	(W/m^2)	25	25	25	25
Heating set point temperature	(°C)	20	20	20	20

All buildings are assumed to be retrofit projects and therefore follow the existing buildings guidance where available. Having defined the building types these were then used with a single climate, taken as Dublin in the Present (historical weather data) to estimate the useful cooling hours. To estimate whether or not it was possible to supply the ventilation rate required in order to achieve the useful cooling hours a ventilation opening configuration was defined as outlined in Table 6.2. The same opening design was adopted for all simulations. Once all parameters had been defined along with the climate data the following simulations were completed:

- Each building scenario simulated for the present Dublin climate
- Building scenario 2 simulated for the present climate for all five Irish geographical locations
- Building scenario 2 simulated for IPCC A1B-2030 climate for Cork, Dublin, Athlone
- Building scenario 2 simulated for IPCC A1B-2050 climate for Cork and Dublin.

Table 6.2: Ventilation Opening Design

Input Parameter	Units	Value
Opening Height	(m)	1.5
Opening Width	(m)	0.8
Free Area Ratio	(m)	0.6
Discharge Coefficient	(-)	0.6
Number of Openings	(-)	7
Supply Air Temperature Low Limit	(°C)	10
Opening Area to Floor Area Ratio	(%)	5.25%

B. Results and Analysis

1. Archetypal Office Buildings in Ireland

The results from the scenario comparisons outlined above are presented below. The first comparison looks at the extent of useful cooling hours from the external ambient air for 4 different building types. These use the same internal heat gains and occupancy characteristics (occupancy from 08:00 – 17:00 each day with a lunch break at 13:00 where there are no internal gains for that hour). Figure 6.1 shows the annual summary of cooling state for each building type.

Table 6.3: Summary Statistics for enhanced VC for all building types

Building	VC hours	(%)	Mean Annual ACR	STD Annual ACR	Max Annual ACR
Part L 2008 retrofit	2736	75	3.5	2.6	16.2
Part L 2017 retrofit	2979	82	3.5	2.3	15.3
Part L 2017 new	3091	85	3.6	2.3	15.3
NBERT	3204	88	3.4	2.0	14.2

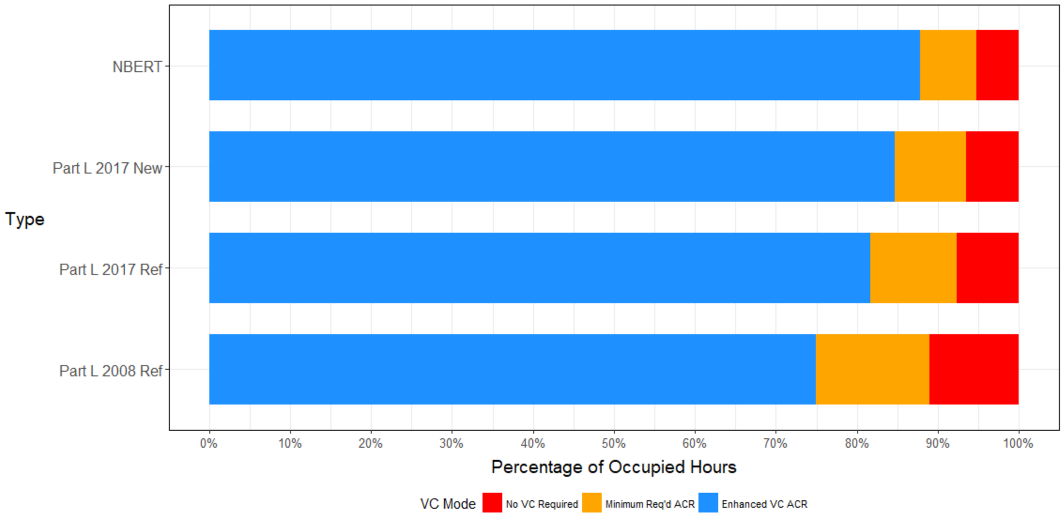

Figure 6.1: Percentage of hours for each building type where cooling is required and VC from the external ambient climate can satisfy requirements.

It can be seen that the NBERT building has the highest requirement for cooling and this can be met using the external ambient air. Table 6.3 shows the hours for enhanced VC along with the mean and standard deviation for the required airflow rate to deliver the cooling to each building. In all buildings cooling is now the dominant thermal state with only 15% or less of the hours requiring heating. This is evidence of the major challenge ahead facing low energy buildings into the future. In general there is not a large spread between the 2017 buildings and NBERT. This suggests that while the fabric is important in determining the likely cooling requirement other factors may play a more significant role. We see no occurrence of the "VC not possible" mode.

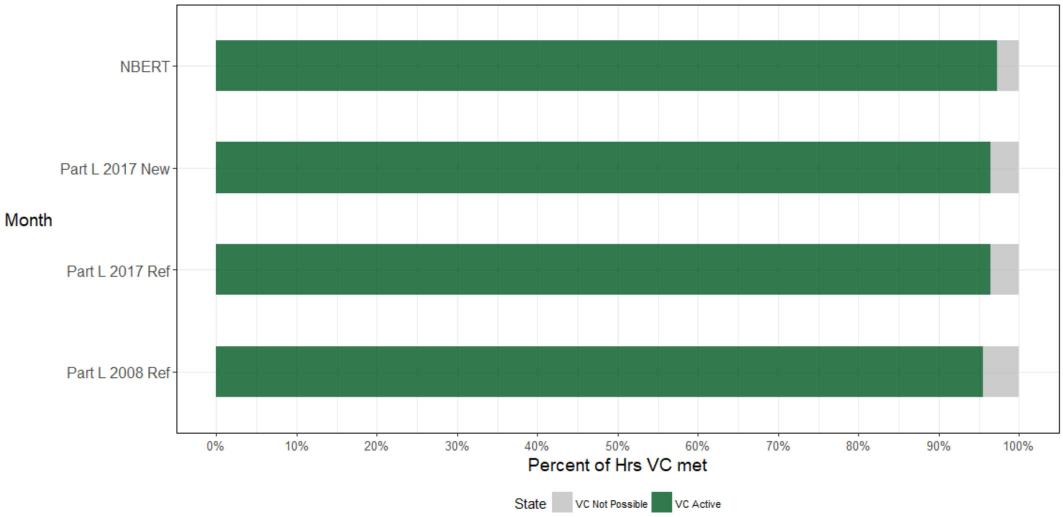

Figure 6.2: Percentage of annual occupied hours in each building where the ventilation opening is able to provide the required airflow rate to provide the useful VC in Figure 6.1.

This occurs if the external ambient temperature is above the upper thermal comfort limit (including an offset to prevent cooling when then envelope temperature difference is too low, set at 3K currently). Ireland's climate is such that we have cooling potential year round for a given building. Returning again to the 4 archetypal buildings in Figure 6.1 above we need to establish whether or not it is feasible for the single sided ventilation opening design outlined in Table 6.2 to provide the airflow rate satisfactorily during the occupied hours. Figure 6.2 shows that for all buildings the proposed design can meet the required airflow rate for over 95% of the annual occupied hours. Recall that the cooling potential analysis above calculates the required airflow rate to maintain the internal environment at or below the upper thermal comfort limit according to the adaptive model in EN15251:2007 [ref]. This means that where this airflow rate can be met then an acceptable internal thermal environment is achieved. So, in summary Figure 6.2 shows that comfortable conditions can be maintained for over 95% of the year irrespective of building type. However, it should be noted that the remaining 5% of annual occupied hours is concentrated in a short period of time. Figure 6.4 shows that for the NBERT building these hours of unacceptable internal environment are concentrated in June, July and August with nearly 15% of the occupied hours in June and July having indoor air temperatures above the acceptable upper limit.

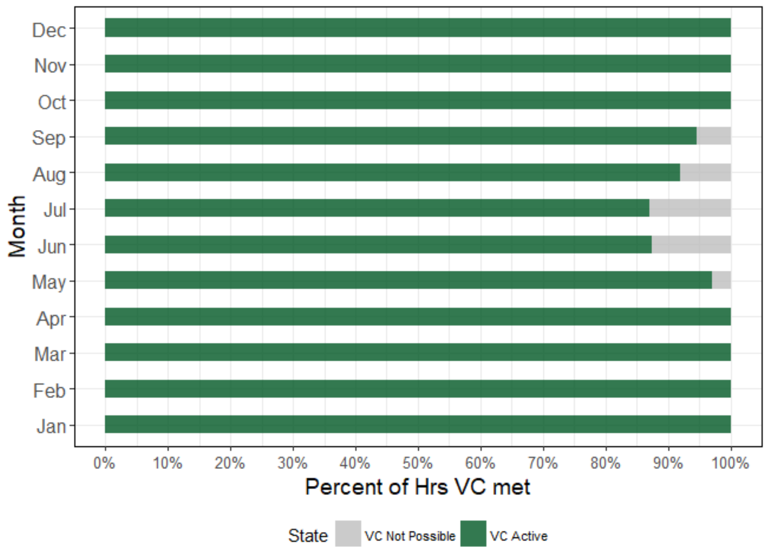

Figure 6.4: Percentage of monthly hours in NBERT that the ventilation system can meet the required airflow rate.

If we consider different values of internal gains for the Part L 2017 retrofit scenario alone we see a large reduction in active VC, i.e. the system cannot meet the required airflow rates necessary to unlock VC for a larger number of hours each month. The need for the external ambient air to provide useful cooling in a high performance office building increases dramatically.

In summary the following points should be noted:

- Irrespective of envelope fabric performance from Part L 2008 onwards there is a need for cooling in our buildings for over 70% of the annual occupied hours.
- The effects of thermal storage in the structure is currently omitted from the VCPA tool. This will reduce the amount of time the method estimates a building will be in cooling mode.
- A natural ventilation design using single sided ventilation can provide the required cooling airflow rate for 95% of the occupied hours. This includes a supply air low temperature limit of

10°C. The design is based on a 5.25% ratio of opening area to floor area. The current Ventilation TGD Part F recommends 5%.

2. Typical Climates in Ireland

The results from the climate scenario comparison are presented below. A Part L 2017 retrofit building has been used. This is building S2 in Table 6.1 above. A similar cooling potential is observed for each of the five locations selected in Ireland. A high cooling potential exists for natural VC systems in Ireland. The existing climate is well suited to cooling solutions that do not use mechanical cooling. There is a narrow spread of variation between locations around Ireland with most having a need for enhanced cooling between 75% and 85% of the annual occupied hours.

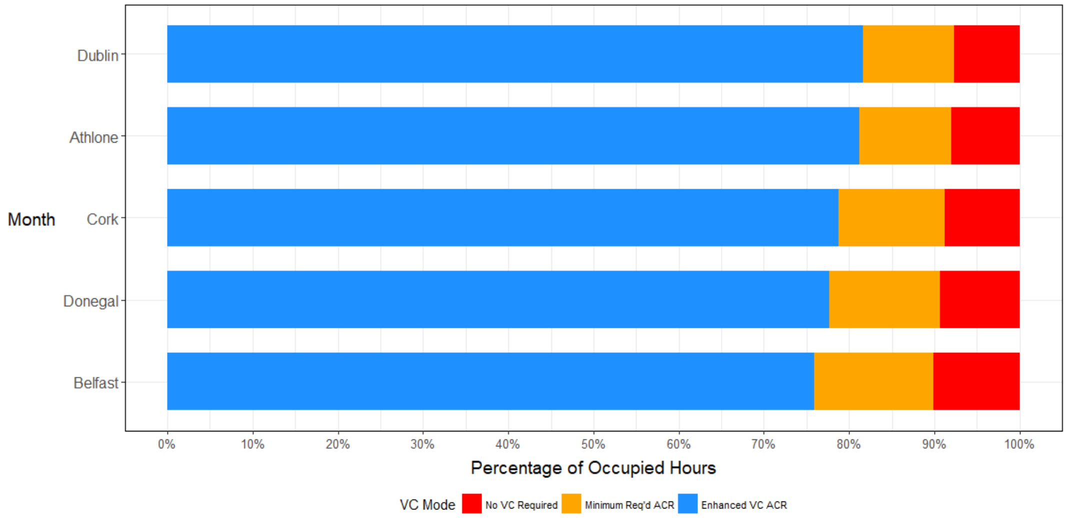

Figure 6.5: Percentage of annual hours where VC is useful for Part L 2017 Office Building in various locations around Ireland for the present climate (historical climate data).

The IPCC emissions scenarios proposed different levels of CO_2 in the atmosphere depending on different societal, economic and technological changes over the next 100 years. These scenarios have been used by various research organisations to produced representative hourly future weather files for use in assessing the impact these future climates will have on energy systems and technologies.

Table 6.4: Comparison of present and future climates for hours of enhanced VC in Part L 2017 retrofit building

Location	Present Climate		Future Climate (a1b)	
	VC hours	(%)	VC hours	(%)
Athlone	2961	81	2949	81
Belfast	2769	76	2839	78
Cork	2876	79	3047	84
Dublin	2979	82	3029	83
Donegal	2831	78	2889	79

The a1b IPCC emission scenario was adopted for the five locations with a horizon of 2030 to assess whether there will be a measureable change in the amount of useful cooling available as well as whether or not there will be an increase in the number of hours that the ventilation system design cannot provide the required airflow capacity needed. This is a medium impact scenario. Table 6.4 compares the Present VC hours with the future 2030 VC hours. Cork appears to the only locations with a significant increase in the number of hours that VC is required. There is no significant increase for the remaining locations. This may be related to the medium level IPCC scenario chosen. Nonetheless, cooling is the dominant operating mode for each location, now and in the future. Further research is needed into this, incorporating the added effects of important phenomena such as thermal mass, as free cooling will become an important climate mitigation strategy in the future. Policy informing research is needed to direct new regulations in the area of cooling and avoidance of unintended consequences such as building overheating.

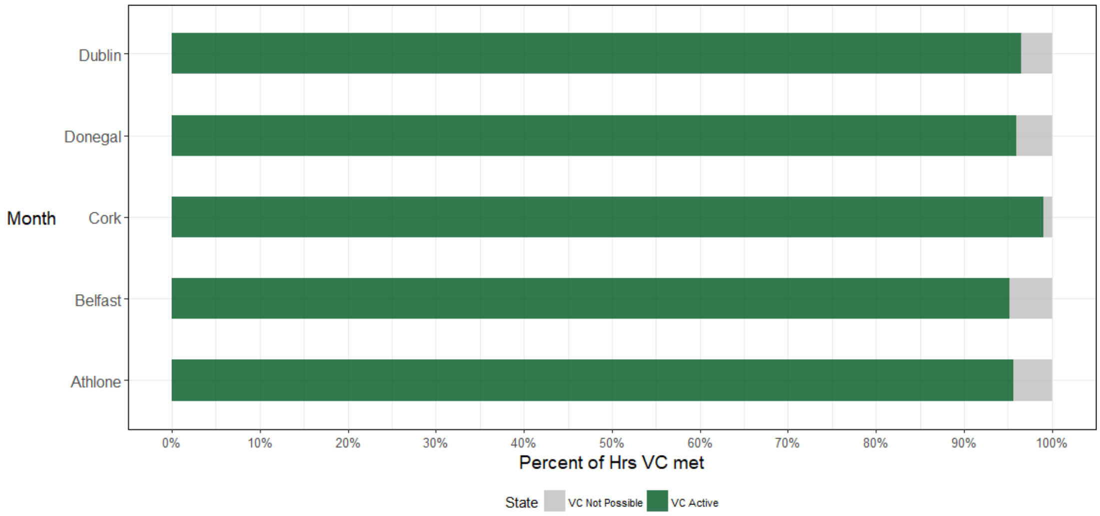

Figure 6.5: Percentage of annual occupied hours at each location where the ventilation opening is able to provide the required airflow rate.

Figure 6.5 shows that for the part L 2017 building at all locations assessed in Ireland the proposed ventilation design can meet the required airflow rate for over 95% of the annual occupied hours. In cork it is close to 100% of the occupied hours. This demonstrates good cooling potential with single sided ventilation and a 5.25% POF. Figure 6.6 presents the difference in the number of hours that the required VC can be met when the building is assessed for the 2030 climates. A reduction in the hours where the required airflow rate to provide VC can be met is shown as a negative value while an increase is shown as positive. A significant increase in the hours where VC can be met is evident in Dublin with over 100 additional annual occupied hours. Belfast and Donegal exhibit reductions in the hours where VC can be satisfactorily met. There seems to be a trend where northern locations are seeing a reduction in VC while midlands and southern locations are seeing an increase. This may be related to the complicated relationship between higher ventilation rates being required due to higher ambient temperatures and increase buoyancy driven airflow through the openings due to potentially higher temperature differences across the envelope. Further research is needed to further investigate this phenomena.

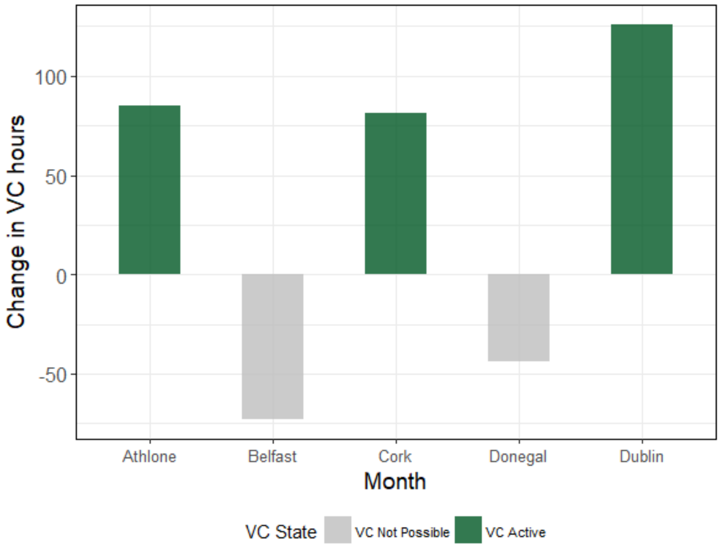

Figure 6.6: Percentage of annual occupied hours at each location where the ventilation opening is able to provide the required airflow rate

In summary the following points should be noted:

- Given the small land mass of Ireland and the consistent koppen climate classification of Cfb everywhere it is not surprising that there is only a maximum 6% variation in cooling potential between different cities.
- Ireland demonstrates very good climate cooling potential using untreated external ambient air with no instances of the external air temperature being above the upper thermal comfort limit throughout the annual occupied periods.
- When the future climate was assessed for cooling potential using a mid-range CO_2 emissions scenario very little difference was exhibited in all locations expect for Cork City where a 5% increase in cooling was required. Increased cooling was shown at all locations.
- In Dublin, up to 125 hours of additional active VC was able to be provided from the ventilation design when assessed for the future climate. In some locations there was an increase in the number of hours in 2030 where VC could not be supplied thus amplifying the risk of overheating in buildings in the future
- An analysis with a more extreme IPCC emissions scenario will increase the amount of estimated cooling required in the future. .

C. Conclusion

Ireland is well suited to passive VC. When a combination of the external ambient climate and a building regulation compliant office are assessed for the likely cooling potential available it shows that VC with an enhanced airflow rate is required over 75% of the time. The required airflow rate for all cooling can be provided over 95% of the annual occupied hours using a simple single sided ventilation configuration. While the study is a simple demonstration exercise it highlights the important role well designed natural ventilation strategies can play in meeting the challenges of delivering low energy buildings with good healthy internal environments. Legislation should continue to exploit the advantages of the Irish climate to minimise cooling loads in buildings and further reduce the risk of overheating now and in the future. In its next revision, the VCPA tool needs additional functionality such as the incorporation of the energy storage effects of thermal mass, new ventilation strategies with better performance potential, new locations and time horizons for assessment, the possibility to test multiple orientations and finally, pre-loaded information and guidance on areas such as typical occupancy patterns and building usage profiles. Nonetheless, the study has shown that there is good cooling potential using natural ventilation in Ireland and any decision to adopt mechanical cooling solutions should be only considered when passive VC strategies have been properly investigated and identified as being unsatisfactory for evidence based reasons.

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