

# FORMULATING A BUILDING CLIMATE CLASSIFICATION METHOD

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## ABSTRACT

When country champions participating in the International Energy Agency Task 40 project on Net Zero Energy Buildings were asked to classify their countries climate, six of the participating countries categorised the residential and non-residential buildings, placed in the same location, into different climate zones. This indicated that a climate zoning for buildings that is based purely on the external climate conditions is not sufficient. This paper proposes an adjustment of the traditional approach to climate classification for buildings by utilising thermal simulation to formulate a building climate classification. This produces a climate indicator that is founded on the locations external conditions and the reference buildings thermal performance.

## INTRODUCTION

This study aims to 1) establish a method for classifying climates that is not based solely on the external climate, but also takes into account the nature of the building and its location; and 2) identify whether there is a need to adjust the traditional climate zoning approach.

The goal is to produce a climate indicator that is founded on a location's external conditions and a reference building's thermal performance. The thermal performance is based on the heat gains and losses, and the internal heating and cooling consumption for a particular building type in a certain location. Thus, the climate classification is not purely the external climatic conditions, but also accounts for different countries' building requirements and the differences between residential and non-residential buildings.

## STUDY SIGNIFICANCE AND BACKGROUND

The significance of this study is exemplified when country champions participating in the International Energy Agency Task 40 project on Net Zero Energy Buildings were asked to classify their countries climates (International Energy Agency - Solar Heating and Cooling Programme 2011). The reason that each countries climate were classified is to categorise the building's energy efficient design and

technologies in a way that determined its climate challenges. In order for buildings to be Zero or Low energy, they need to decrease the need for space conditioning. The climate classification is intended to categorise each building in way that highlights what the biggest space conditioning challenge/s are for the building. This does not mean the buildings do not need to be purely heated or cooled, but the largest challenge comes from the most dominant space conditioning process. Thus, a building in a cold climate would have the largest challenge when reducing the energy consumption for heating, whereas a building in a hot climate would be the opposite.

One IEA participant from each participating country was asked to classify their countries' dominant climatic feature. The climates were zoned as: Heating Dominated, Cooling Dominated, and Heating and Cooling Dominated. Six of the participating country champions categorised the residential and non-residential buildings, placed in the same location, into different climate zones.

Table 1 displays the original climate zones into which the IEA country champions placed their countries' Residential and Non-residential buildings. The highlighted countries are the examples that placed their residential and non-residential buildings in different climate zones.

*Table 1 – Original IEA Participating Countries Climate Classifications (Champions 2010)*

Cooling Dominated	Heating Dominated	Heating and Cooling Dominated
AU, USA-Hawaii and California, F-Réunion	UK, <u>IT -Res.</u> , <u>A-Res.</u> , <u>DE-Res.</u> , <u>CA-Res.</u> , <u>DK-Res.</u> , <u>ES-Res</u> & <u>Barcelona</u>	AU-Melbourne, P, NZ, F, NE, K, USA, B, <u>DK-Non Res.</u> , <u>IT-Non Res.</u> , <u>DE-Non Res.</u> , <u>CA-Non Res.</u> , <u>A-Non Res.</u> , <u>ES-Non Res</u>

Therefore, the nature of the building altered the selection of the climate zone. This indicates that a

climate zoning for buildings that is based purely on the external climate conditions is not sufficient.

This study tests whether a new method of climate classification would more accurately classify the building challenges than a traditional climate classification based merely on the external climate factors.

## EXPERIMENT AND SIMULATION OUTLINE

The study method is to display the traditional climate classification zones for seven locations and compare these to the results of the proposed building climate classification undertaken on the same seven locations. Two locations from a traditionally known Heating Dominated, Cooling Dominated, and Heating and Cooling Dominated climate are chosen for this study. The seven climate locations assessed in this study are: Berlin-Germany, Copenhagen-Denmark, Wellington-New Zealand, Hawaii-USA, Los Angeles-USA, and Melbourne-Australia.

### **External Climate Classification Method**

The external climate-based zoning is undertaken using the Ecotect climate classification tool (Autodesk Incorporated 2011) which overlays a specific location's Average Monthly Maximum temperatures onto a psychometric chart. "The Ecotect Climate Classification tool divides a Psychometric chart into regions characteristic of different climate types. (Natural Frequency 2011)" The overlaid Average Monthly Maximum temperatures relate to the seven external climate regions. The Average Monthly Maximum temperatures are shown on the chart as a shaded area between 12 points representing each month (Natural Frequency 2011). The locations annual temperatures and humidity's all fall in this shaded area.

The Ecotect Climate Classification tool uses a weather file to represent a certain locations external climatic conditions. This study is testing and classifying typical climate conditions for the seven locations. Thus, Typical Meteorological Year (TMY) EnergyPlus weather files are used in the Ecotect assessment (US Department of Energy 2011).

One or multiple climate regions are associated to each location. These assigned zones are based on the monthly extremes and highest percentage of time the temperatures are located in a particular climate region. The climate zones are similar to the Koppen climate zones (University of Veterinary Medicine Vienna 2011). The Koppen zones are labelled in three different levels: First, the four 'Main climates': Equatorial, Arid, Warm temperate, and Snow; Next, the six 'Precipitation levels': desert, steppe, fully humid, summer dry, winter dry, and monsoonal; and Third, the six 'Temperature degrees': hot arid, cold arid, hot summer, warm summer, cool summer,

extremely continental. A fifth 'Main Climate': Polar, in subdivided into Polar Tundra and Polar Ice categories. Otherwise these three climate indicators subdivide the world into 30 basic 'types' being relevant combinations of Main climate, Precipitation level and Temperature (e.g. Arid+Desert+Hot or Arid+Desert+Cold). Often in architectural climate analysis such as that undertaken in Ecotect these 30 types are reduced to classifications based on definitions based upon a combination of the temperature and precipitation levels: hot dry, hot humid, warm dry, warm humid, moderate and cool.

### **Building Climate Classification Method**

The proposed method for the building climate classification is undertaken by simulating residential and non-residential reference buildings in SUNREL (National Renewable Energy Laboratory 2010). "SUNREL is a hourly building energy simulation program that aids in the design of small energy-efficient buildings where the loads are dominated by the dynamic interactions between the building's envelope, its environment, and its occupants (National Renewable Energy Laboratory 2010)"

There are three reference buildings used in this climate study. The reference buildings are four and five zoned models. The models are:

1. 100m<sup>2</sup> four-zoned Residential building model (Figure 1);
2. 100m<sup>2</sup> four-zoned Non-Residential building Model (Figure 1); and
3. 1000m<sup>2</sup> five-zoned Non-Residential building model (Figure 2).

The models are built in this way to simulate accurately the heat gains and losses, and energy consumption that are present across the reference building. The reference buildings test a range of floor area sizes to assess whether the internal loads play a pivotal role in the climate zone results or does the large internal core zone have the largest impact.

The reference buildings have consistent Window to Wall Ratios (WWR). The building area size, internal gains, and Heating, Ventilation and Air-conditioning (HVAC) set points and schedules change between the residential and non-residential building types. In addition, the buildings' insulation values change depending on the local building standards.

The Window to Wall Ratio (WWR) is kept consistent. Both the residential and non-residential models have a WWR of 50 percent.

The insulation values from local building standards for the seven locations are displayed in Table 2. Five of the locations have different insulation requirements for residential (R) and non-residential buildings (NR).

Figure 1 – Four Zone 100m<sup>2</sup> Residential and Non-Residential Reference Building Models

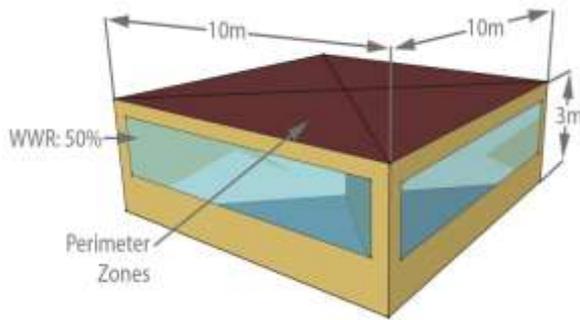
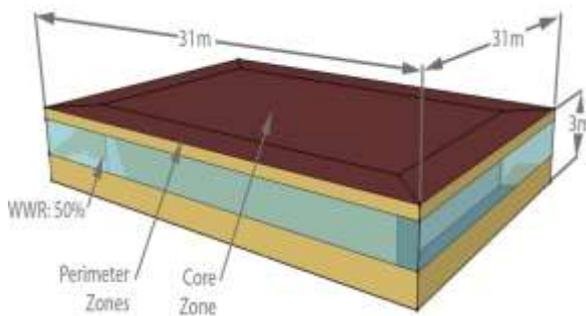


Figure 2 - Five Zone 1000m<sup>2</sup> Non-Residential Reference Building Models



Some assumptions have been made when establishing the insulation values. When there are no requirements for glazing, the R-Value is assumed as a single glazed window. The USA R-values vary between building types due to the nature of the construction: Residential is Timber framed; and Non-residential is Steel – framed construction.

Table 2 – Building Element Insulation Values

Location		R-Values (m <sup>2</sup> ·K/W)			
		Wall	Floor	Roof	Glaz
Sweden	R	10.00	10.00	12.50	0.91
	NR	5.56	6.67	7.69	0.77
Berlin		3.57	2.86	5.00	0.77
Copenhagen		3.33	5.00	5.00	0.56
Wellington	R	2.00	1.30	3.30	0.26
	NR	1.30	1.00	2.20	0.15
Melbourne	R	2.80	1.00	3.20	0.15
	NR	1.30	1.0	2.20	0.15
New York	R	3.00	5.20	6.70	1.80
	NR	3.20	1.80	3.50	1.80
Hawaii	R	2.30	1.00	5.30	0.80
	NR	2.30	1.00	2.60	0.80

Sweden: (Boverket 2011)  
 Berlin: (German Ministry of Justice 2011)  
 Copenhagen: (Erhvervs-Og Byggestyrelsen 2011)  
 Wellington: (Standards New Zealand 2007)  
 Melbourne: (Australian Building Codes Board 2010)  
 USA: (American Society of Heating, Refrigerating and Air-Conditioning Engineers 2010)

The residential and non-residential models have differing internal gains, and Heating, Ventilation and Air-conditioning (HVAC) set points and schedules. These are considered the most likely to be the largest influences on the performance of the two building types. Single family residential buildings' space conditioning is expected to be driven mainly by the external climate, whereas non-residential buildings are likely to be more heavily influenced by the internal gains in the building. A number of assumptions are made to derive the internal gains and HVAC schedules. The assumptions are:

*Residential Reference Building*

- There are 40W of latent heat and 70W of sensible heat produced per person (American Society of Heating, Refrigerating and Air-Conditioning Engineers 2009).
- Three people occupy the building all day.
- There are 200lumens of light per square metre of floor area. The lights are scheduled to be on from 7pm to 11pm.
- No internal equipment is modelled.

*Non-residential Reference Building*

- 40W of latent heat and 70W sensible heat produced per person (American Society of Heating, Refrigerating and Air-Conditioning Engineers 2009).
- The building is occupied during the hours of 8am to 5pm.
- There is one person per 10 square metres of floor area (Standards New Zealand 2007).
- There are 200lumens of light per square metre of floor area and is all latent heat. The lights are scheduled to be on from 8pm to 6pm.
- One 65W desktop computer and one 40W LCD screen per 10 square metres of floor area ((EECA) 2007).

These assumptions result in the internal gains, and HVAC set points and schedules displayed in Table 3 and 4.

Table 3 – Building Type Internal Gains

Internal Gains		
Type	Residential	100m <sup>2</sup> and (1000m <sup>2</sup> ) Non-residential
People	360W	1200W (12000W)
Lights	300W	720W (7200W)
Equipment	0W	800W (8000W)
Schedules	All day	8am-5pm

The infiltration rates are:

- Residential – 0.5ACH (Standards Association of New Zealand 2009)
- Non-Residential – 1.2ACH (10L/s.person) (Standards New Zealand 2007).

The heating, ventilating and cooling set points are based on recommended internal temperatures for health and comfort (World Health Organisation 1985) (Department of Building and Housing 2011).

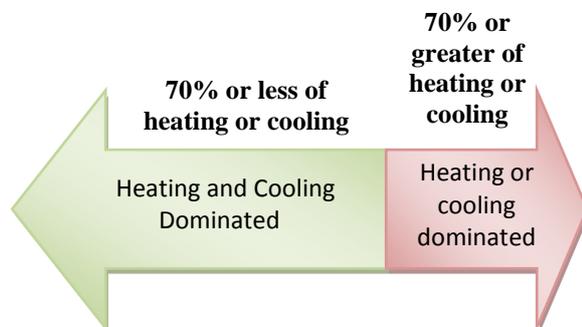
Table 4 – Building Type HVAC Settings

HVAC Set Points and Schedules		
Mode	Residential	Non-residential
Heating	18 °C	20 °C
Ventilation	23 1ACH	Mechanical= 23 °C 1ACH Natural= 23 °C 10ACH Night Ventilation= 22 °C 20ACH
Cooling	25 °C	25 °C
Schedules	All Day	Office Hours= 8am-5pm Night Ventilation= 10pm-6am

The SUNREL reference-building model simulation uses the same TMY weather file that the Ecotect Climate Classification tool used. The same TMY weather file is used in both assessments to prevent any inconsistencies in the two climate zonings.

The SUNREL simulation results highlight the dominant space conditioning process. To define dominant, an arbitrary percentage is set to aid in the zoning of each building climate region. Dominated is defined as making up 70 percent or greater of the specific space conditioning need (i.e. heating dominated, or cooling dominated). Whereas, if the space conditioning needs is 70 percent or less, it is mixed dominated (i.e. Heating and Cooling Dominated). Figure 2 illustrates this building climate zone definition boundary.

Figure 2 – Building Climate Zone Definitions



### The Comparison of the Climate Classification Systems

In order to conclude whether a new building climate classification system is warranted, a comparison against the traditional method needs to be

undertaken. The comparison is undertaken using as the baseline the climate zones established by the IEA country champions. The Ecotect Climate Classification tool and the Building Climate Classification are compared against this baseline and each other. This establishes whether the traditional external climate classification suffices to classify the challenges buildings have in a particular location, or whether the new climate classification method more accurately classifies the building challenges.

### DISCUSSION AND RESULT ANALYSIS

The results that follow present the two climate classification methods and a comparison of the two methods against the original climate zonings made by the IEA Task 40 participants.

#### External Climate Classification Method

Each of the seven locations' TMY weather files are overlaid and can be categorised according to the climate zones. Figures 3 to 9 display the results of the external climate zoning, ranging from the coldest to warmest external climates. The figures present the psychometric charts with each locations overlay as a solid coloured area representing the temperature and humidity levels throughout the year. Each locations' data is highlight to aid in the zoning of each climate. The coloured background displays the dominant space conditioning process associated with the climate zones. It also highlights the challenges connected to that zone.

It is seen in Figure 3 that Stockholm, Sweden is predominantly below and in the cold climate zone, thus is categorised as a cold climate.

Figure 3 – External location results for Stockholm

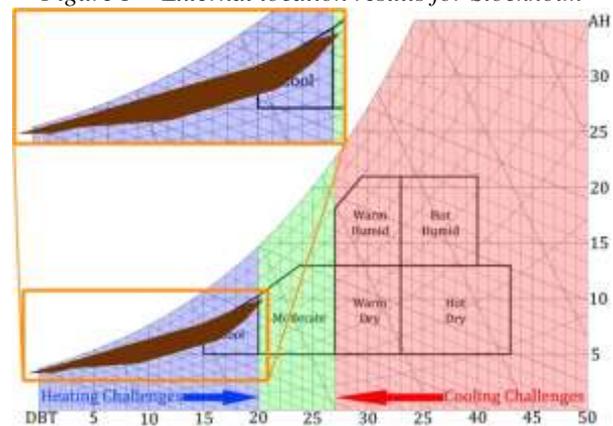


Figure 4 shows that Copenhagen, Denmark is predominantly below and in the cold climate zone. It is classified as a cold climate.

Figure 5 illustrates that Berlin, Germany is predominantly below and in the cold climate zone. It is categorised as a cold climate.

Figure 4 – External location results for Copenhagen

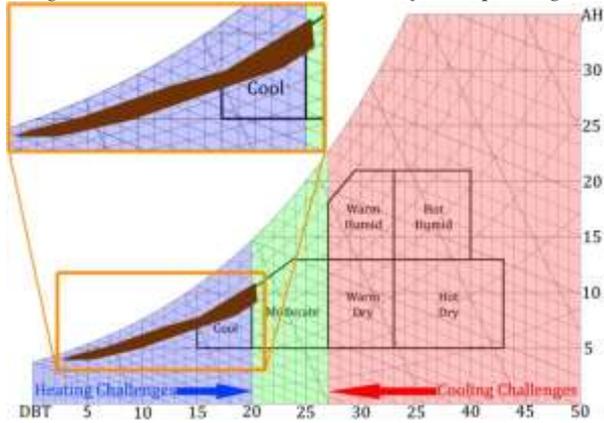


Figure 7 – External location results for Melbourne

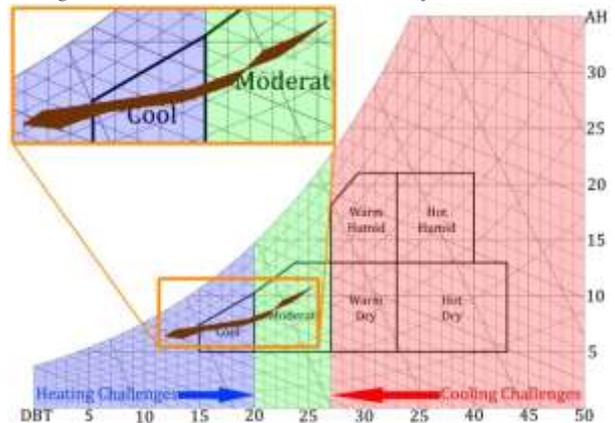


Figure 5 – External location results for Berlin

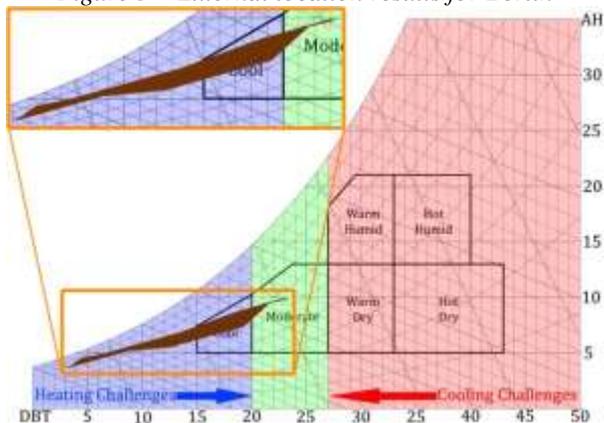


Figure 8 shows New York, USA having temperatures and humidity ranging from below the cold zone to the warm humid climate zone. This means the location is a mixed cold and warm climate.

Figure 8 – External location results for New York

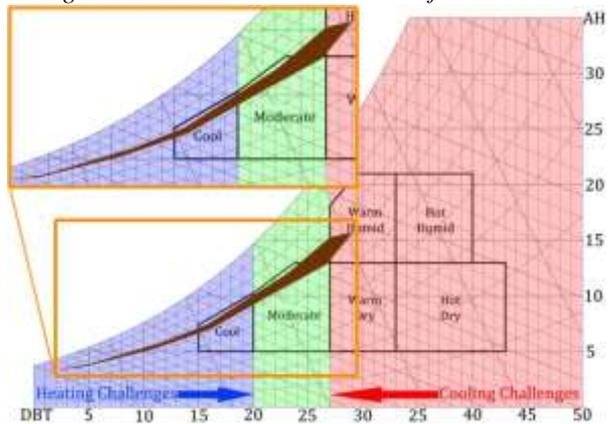
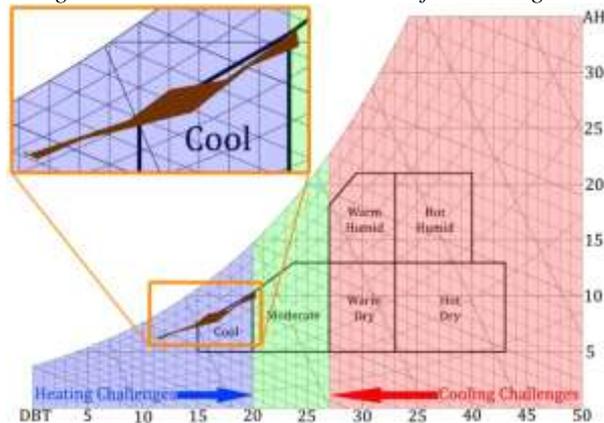


Figure 6 shows that Wellington, New Zealand is below and predominantly in the cold climate zone, thus it is a cold climate.

Figure 6 – External location results for Wellington



It is seen in Figure 9 that the Hawaii location is above the moderate and in the warm humid climate zones. It is categorised as a warm humid climate.

Figure 9 – External location results for Hawaii

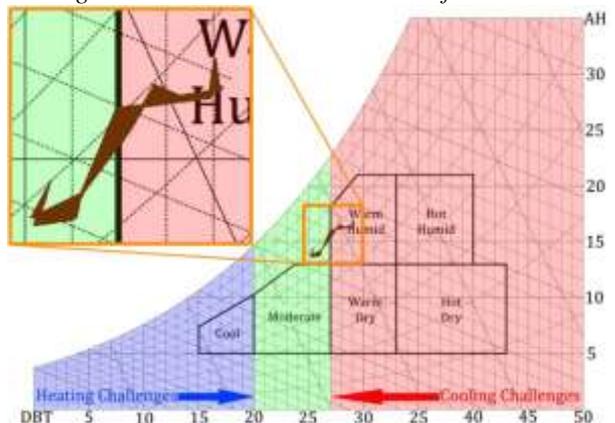


Figure 7 illustrates that Melbourne, Australia is predominantly below and in the cold climate zone, even though it is partially in the moderate climate zone. Thus, it is classified as a cold climate.

For architectural design purposes a climate zone should highlight the challenges buildings will face due to the external climate. In a cold climate, the challenge is heating the internal space to keep the

occupants comfortable. In a warm climate, the challenge is to cool the space. In a cold and warm climate, the challenge is to heat and cool the building interior.

These traditional climate zone analyses do not match the climate challenge labels identified by the IEA ‘country champions’. Unlike the proposed classification they do not take into account the nature of the building or the local building code requirements to meet the challenges of the climate. Categorising all buildings in a particular location to have, purely, the external climate’s associated challenge seems unsuccessful. What remains to be tested is whether the proposed system functions in consistent manner. The next section analyses the simulation results per climate in more detail to consider whether this type of simulation based climate analysis might also provide general lessons for design in a climate.

### Building Climate Classification Method

Figure 10 and 11 display for all seven climates the heating energy use (red), solar gains (yellow), and internal heat gains (orange) as positive gains; while the infiltration (grey), windows (light green), ambient (dark green), and ground losses (brown), ventilation energy use (light blue) and the cooling energy use (dark blue) as negative losses. Figure 10 compares the 100m<sup>2</sup> residential and 100m<sup>2</sup> non-residential reference building results. Figure 11 displays the results of the 1000m<sup>2</sup> non-residential reference building.

Figure 10 – Internal heat gain and losses in the 100m<sup>2</sup> reference buildings

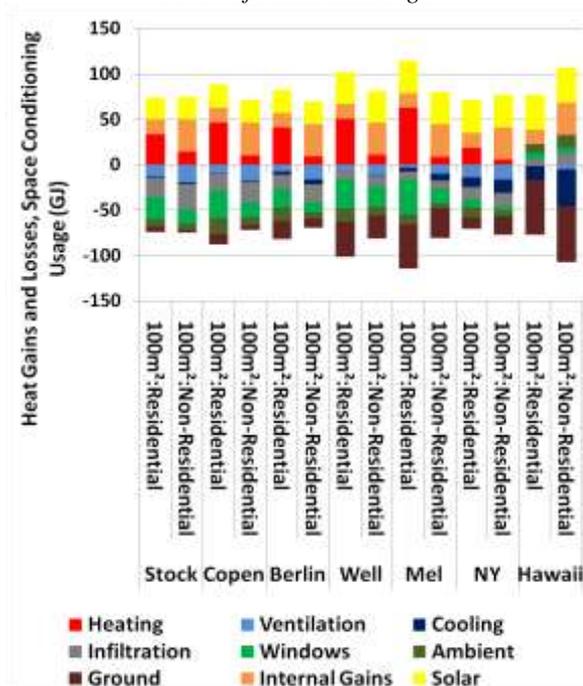
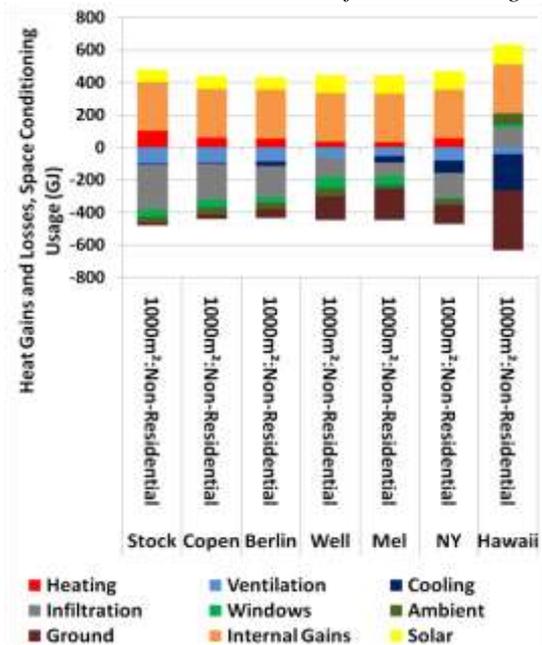


Figure 11 – Internal heat gain and losses in the 1000m<sup>2</sup> Non-Residential reference building



The locations are graphed in order from coldest to warmest external climate. The heat gain and loss results from the various locations show that the local building code plays a large role in the interaction with the climate. Stockholm, Berlin, and Copenhagen have more cold extremes when comparing their external climate to Wellington and Melbourne, yet they have less heating needs (in the red) and far less heat losses through the windows (in light green) and ground (in brown) in the residential reference building. This is purely due to the building code requirements in each location.

The building typology also has a significant impact on the building gains and losses. The most prominent change is to the space conditioning needs. The non-residential reference buildings are much more cooling orientated (in light and dark blue) when compared to the residential reference buildings. This reduction in heating is due to the higher internal commercial loads (in orange). This is evident in both the 100m<sup>2</sup> and 1000m<sup>2</sup> non-residential reference building and is even true with the non-residential building insulation requirements being more lenient in the majority of the locations tested.

In the cold climates the interaction of infiltration, ambient and windows all create losses in energy. However, in the warm climate this interaction becomes an energy gain. This seems to be due to the warmer temperatures providing more heat gains to the building. More heat gains, results in more cooling needed.

Figure 12 - Percentage split of the space conditioning requirements for the three reference buildings in the seven locations

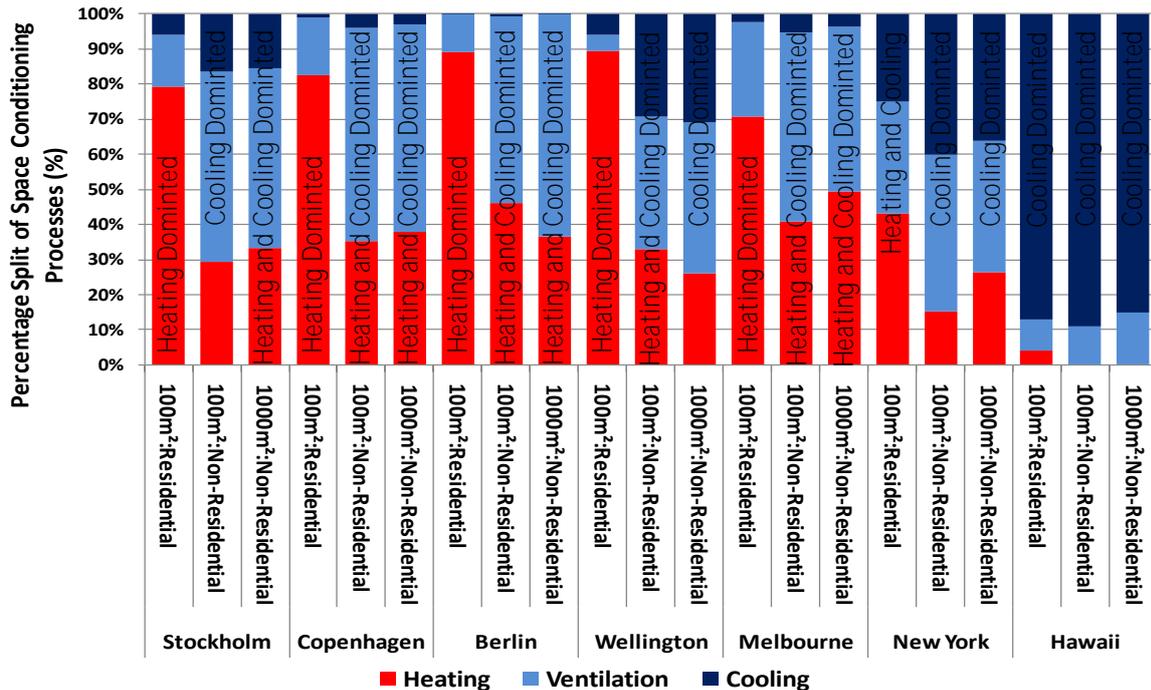


Figure 12 displays the percentage split between the heating requirements (red), the ventilation requirements (light blue), and the cooling requirements (dark blue) for the three reference buildings in the seven locations.

In the cold, and mixed cold and warm climates tested, the dominant space conditioning need changes between the residential and non-residential reference buildings. As can be seen by Stockholm, Copenhagen, Berlin, Wellington, and Melbourne (the Koppen ‘cold’ climates), the residential buildings are heating dominated, while the non-residential buildings are heating and cooling dominated, or cooling dominated. The difference in the heating and cooling consumption in the 100m<sup>2</sup> buildings is due to the number of people, lights and internal equipment. It can be seen that some of the 1000m<sup>2</sup> non-residential reference buildings dominant space conditioning process is different when compared to the 100m<sup>2</sup> non-residential reference building. This results from the large internal core. It suggests that a simulation based climate classification must model buildings of a relevant size as well as of relevant internal gain patterns.

### Climate Classification System Comparisons

The Ecotect climate zones correspond to the three building climate classification zones by making the climate challenges as the dominant space conditioning process. For example, Stockholm is a cold climate and has heating challenges and this corresponds to be a heating dominated climate. In making this comparison, it identified that there are some major differences and some coherency in results between the two climate classification methods.

5 out of the 21 buildings were placed in the same external zone as the building climate zone. These buildings are either residential buildings or in the cooling dominated climate. Due to the residential buildings having lower internal load levels, the internal gains are not severe enough to make an impact on the internal temperatures of the building. This is true regardless of the insulation levels that are required from the locations building code. However in the cooling climate, the insulation does not prevent the overheating of the building and results in no change to the challenges from the climate. The internal gains in the non-residential buildings just add to the overheating and results in more cooling consumption. Resulting in warm climates always being cooling dominated.

The other 16 buildings all have differing climate zones between the external and building climate classifications. All of the 16 buildings are the non-residential reference buildings in cold, and mixed cold and warm climates. The difference in climate zones is due to the commercial internal loads and having a larger floor area, in the case of the 1000m<sup>2</sup> reference building. These two factors reduce the need for cooling drastically and these results are dominated by the higher levels of internal gains. The non-residential buildings essentially move away from the challenges of external climate, and towards being internal climate challenges.

### CONCLUSION

This paper has demonstrated the utility of a method for classifying climates that is not based solely on the external climate. It has shown that a building based climate classification which accounts for the nature

of the building and its local building code can provide design insights far superior to those of the traditional Koppen based approach. The building climate classifications will aid the work being completed in the IEA Net ZEB project (International Energy Agency - Solar Heating and Cooling Programme 2011). It has the potential to be used to providing engineers, architects and designers the required information about the potential of energy efficient design and technologies that are used in buildings in any 'climate'.

The building climate indicator that has been produced has worked with a simple three level definition of climate challenge: heating dominated; cooling dominated; or mixed heating and cooling dominated. It is founded on the basis that a building is climate dominated if one of a reference buildings space conditioning processes is 70% or greater of the total space conditioning load. These three climate zones and a method that accounts for the nature of the building as well as local building standards has created a platform for building based climate classification.

The results from the building climate classification indicate that buildings in cold climates cannot be classified solely by using the external climatic conditions. It has shown that as expected a purely external climate based classification focuses attention on design solutions suited to residential buildings. Buildings with higher internal loads may not be suited to these design solutions.

The results have also shown that hot climates can probably be classified by using the external climate conditions as the internal loads within the buildings only serve to increase the cooling needs further.

The different local building code requirements have a large impact in the buildings energy gains and losses, but they are not large enough to alter the classification for residential buildings in any of the climates. The main influence on these building climate classifications is the internal loads. The results indicate that climates are not one-dimensional and that the building type and local building standards interact with external climates. Therefore changing the challenges faced by the buildings.

This study is the first stage proof-of-concept of an improvement for categorising low energy building design techniques for particular climates. Future work will focus on the nature of the reference building; the issue of the local building code reference values; the question of daylight, natural ventilation potential; and the complexities of humidity.

### Acknowledgements

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