FORMULATING A BUILDING CLIMATE CLASSIFICATION METHOD

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ABSTRACT

Research experts participating in the International Energy Agency (IEA) Task 40 project on Net Zero Energy Buildings (Net ZEB) were asked to classify their countries climate. Six of the participating countries researchers 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 a reference building's thermal performance.

INTRODUCTION

This study aims to 1) establish a method for classifying climates that takes into account the nature of the building and its location, as well as the external climate; and 2) identify whether there is a need to adjust the traditional climate zoning approach.

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. The goal is to produce a building climate classification 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 based purely on the external climatic conditions, but also a countries' building insulation requirements and the differences between building activities.

STUDY SIGNIFICANCE

This climate classification is intended to categorise each building in a way that highlights the biggest space conditioning challenge/s faced by the building. In the IEA Task 40 project on Net ZEBs (International Energy Agency - Solar Heating and Cooling Programme 2011) this climate classification is one technique adopted for classifying design solution sets which match these climate challenges.

For buildings to be zero or low energy, they need to minimise the need for space conditioning. This does not mean a building is purely heated or cooled, but rather the largest design challenge comes from the most dominant space conditioning process. In a cold climate, the largest design challenge is presented when reducing the energy consumption for heating, whereas in a hot climate the design challenge would be the opposite.

EXPERIMENT AND SIMULATION OUTLINE

IEA Task 40 / Annex 52 NZEB Climates

The stimulus for this project was an IEA Task climate classification exercise. One research expert from each participating country in the IEA Task 40 project was asked to classify their country's dominant climatic feature. The climates were zoned as: Heating Dominated, Cooling Dominated, and Heating and Cooling Dominated.

Table 1 displays the original climate zones into which the IEA research experts placed their countries' residential and non-residential buildings. The highlighted countries placed their residential and non-residential buildings in different climate zones.

Table 1 – Original IEA Participating Countries Climate Classifications

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

Six of the participating research experts categorised the residential and non-residential buildings, placed in the same location, into different climate zones. For example, residential buildings in Germany (DE) are classified as being Heating Dominated, but non-residential buildings are classified as Heating and Cooling Dominated.

The nature of the building altered the selection of the climate zone. This indicated that a climate zoning for buildings based purely on the external climate conditions is not sufficient.

The Study Design

The study method compares a traditional climate classification with the proposed building climate classification for seven locations. The seven locations are made up of: four heating dominated climates (Stockholm-Sweden, Berlin-Germany, Copenhagen-Denmark, Wellington-New Zealand); one cooling dominated climate (Kaneohe Bay, Hawaii-USA); and two heating and cooling dominated climates (New York-USA, Melbourne-Australia).

Sweden is not listed as one of the climates participating in the original exercise documented in Table 4. It has been selected for inclusion in the study as a climate representative of areas that experience more extreme cold than the other cold climates but, unlike the potential Canadian or North American examples is not also complicated by excessively hot summers.

Traditional External Climate Classification Method

Traditional external climate based zoning is exemplified by the Ecotect climate classification tool (Autodesk Incorporated 2011). It 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). This means that the locations hourly temperatures and humidities all fall within this shaded area.

The Ecotect Climate Classification tool uses a weather file to represent a certain location's external climatic conditions. This study tests and classifies typical climate conditions for the seven locations. Typical Meteorological Year (TMY) EnergyPlus weather files all in the same format for all locations were used in the Ecotect assessment (US Department of Energy 2011).

One or more climate regions are associated to each location. These assigned zones are founded 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 a 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 that are based upon a combination of the temperatures, and humidities: hot dry, hot humid, warm dry, warm humid, moderate and cool (M Kottek 2006).

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 an 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).

The reference buildings are idealised residential and non-residential buildings for testing the construction and internal loads impact on a locations dominant climatic feature. There are three reference buildings used in this climate study. The reference building models are:

1. 100m^2 four-zoned residential building model (Figure 1);
2. 100m^2 four-zoned non-residential building Model (Figure 1); and
3. 1000m^2 five-zoned non-residential building model (Figure 2).

The models are built in this way to accurately simulate the heat flows (gains and losses), and energy consumption that is present across the reference buildings.

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 whether the large internal core zone would have the largest impact. The details and assumptions used in the three reference building models geometry, construction, schedules, and set points are detailed below.

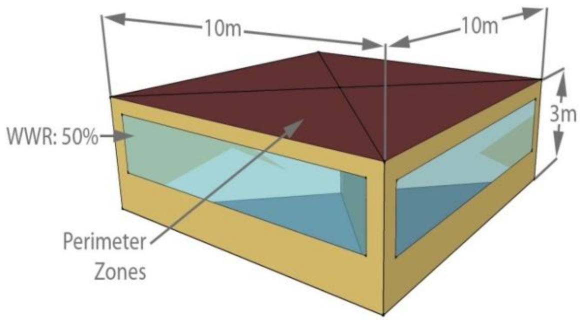

Figure 1 – Four zone 100m² residential and non-residential reference building models

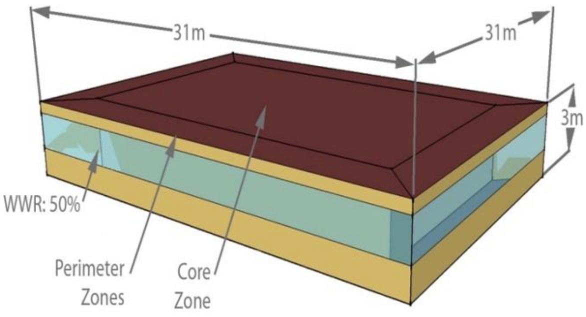

Figure 2 - Five zone 1000m² non-residential reference building models

The Window to Wall Ratio (WWR) is consistent across all three reference building models and is 50 percent.

The minimum insulation values required from the 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).

Table 2 – Building Element Insulation Values

Location		R-Values (m²·K/W)			
		Wall	**Floor**	**Roof**	**Glaz**
Stockholm	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	0.55
	NR	3.20	1.80	3.50	0.55
Hawaii	R	2.30	1.00	5.30	0.45
	NR	2.30	1.00	2.60	0.45

Stockholm: (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 to be the most likely aspects to influence 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

- 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.
- 200lumens of light per square metre of floor area provided by a 36W T8 Fluorescent Tube. The lights are scheduled to be on from 7pm to 11pm.
- No internal equipment is present.

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).
- Building occupancy is during the hours of 8am to 5pm.
- One person per 10 square metres of floor area (Standards New Zealand 2007).
- 200lumens of light per square metre of floor area provided by a 36W T8 Fluorescent Tube. Lighting is scheduled to be on from 8am to 5pm.
- One 65W desktop computer and one 40W LCD screen per 10 square metres of floor area ((EECA) 2007).

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). The aim is a broad 18°C -25°C comfort zone for the residential building as to not overextend the heating and cooling usages. This broad comfort range is based on fit occupants. It does not consider weaker occupants as the building climate classification is not intended to assess this. However, the non-residential reference model has a narrower comfort band of

20°C-25°C as non-residential buildings are typically heated to warmer temperatures.

A ventilation set point and rate are also defined. This is the temperature when the windows are assumed to be opening for natural ventilation to aid in cooling the interior. The ventilation occurs regardless of the duration or time of year. The ventilation rate is an arbitrary value that is set to see the affect it has on the on the interior.
These assumptions result in the internal gains, and HVAC set points and schedules displayed in Tables 3 and 4.

Table 3 – Building Type Internal Gains

Internal Gains		
Type	**Residential**	**100m² and (1000m²) Non-residential**
People	330W	1200W (12000W)
Lights	300W	720W (7200W)
Equipment	0W	800W (8000W)
Schedules	People = All day. Lights = 7pm-11pm	8am-5pm

Table 4 – Building Type HVAC Settings

HVAC Set Points and Schedules		
Mode	**Residential**	**Non-residential**
Heating	18 °C	20 °C
Ventilation	23 °C 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 simulations use the same TMY weather files that the traditional climate classification Ecotect tool uses. The same TMY weather files are used in both assessments to prevent any inconsistencies in the two climate zonings.

The SUNREL simulation results highlight the dominant space conditioning process. The three space conditioning processes used in the building climate classification assessment are heating, ventilation and cooling. To define dominant, an arbitrary percentage is set to aid in the zoning of each building climate region. For the purposes of this study, dominated is defined as making up 70 percent or greater of the buildings space conditioning needs (i.e. heating dominated, or cooling dominated). Whereas, if both the heating or cooling needs are less than 70 percent, the climate is classified as mixed dominated (i.e. Heating and Cooling Dominated). Both ventilation and cooling are considered in the cooling process as they are two aspects of cooling in buildings. Figure 2 illustrates this building climate zone definition boundary.

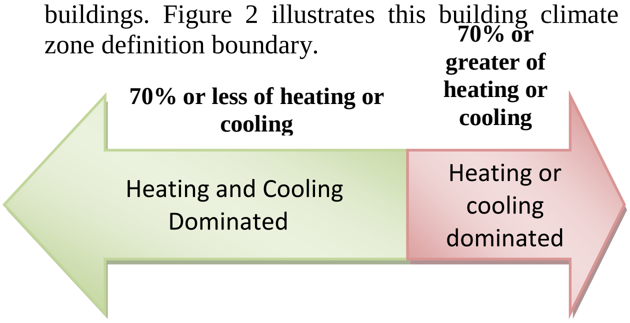

Figure 2 – Building Climate Zone Definitions

The Comparison of the Climate Classification Systems

In order to conclude whether a new building climate classification system is warranted, a comparison of the traditional method against the baseline climate zones established by the IEA research experts is made. The traditional external climate classification and the building climate classification are also 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 proposed climate classification method more accurately classifies the building challenges.

DISCUSSION AND RESULT ANALYSIS

The results that follow present the IEA Task 40 climate location zonings, the traditional climate classification method results, and the proposed building climate classification method results for the seven locations.

Traditional External Climate Classification Results

Figures 3 to 9 display the results of the traditional external climate zoning, ranging from the coldest to warmest external climates. These figures present standard psychometric charts with each locations actual annual temperature and humidities overlaid as a solid brown coloured area. Each locations' results are blown up to aid in the zoning of each climate. The coloured background displays the challenges connected to that climate zone (blue having heating challenges and red having cooling challenges).

Figures 3, 4, 5, and 6 show that Stockholm, Copenhagen, Berlin, and Wellington are predominantly below and in the cold climate zone. They are categorised as cold climates and buildings located in these locations would have heating challenges.

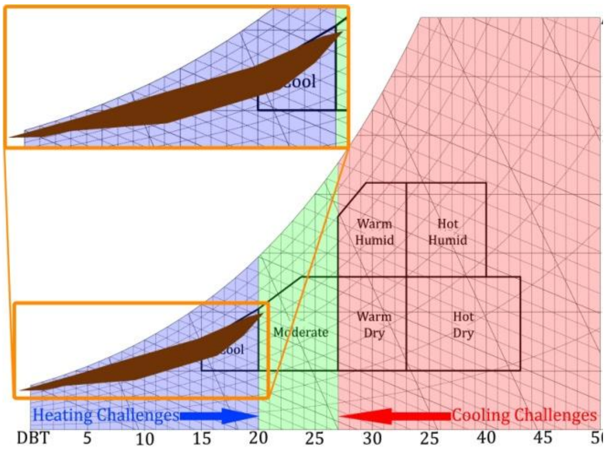

Figure 3 – External location results for Stockholm

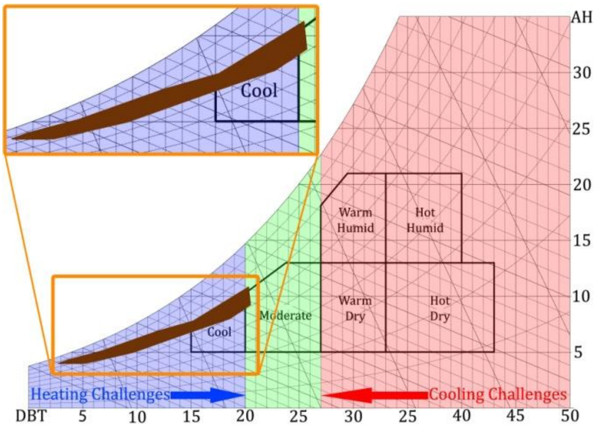

Figure 4 – External location results for Copenhagen

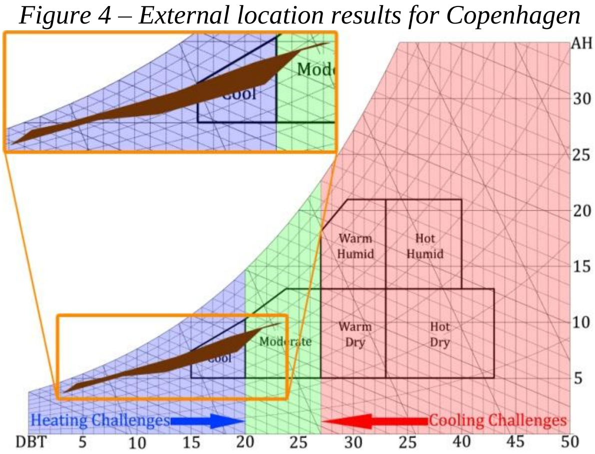

Figure 5 – External location results for Berlin

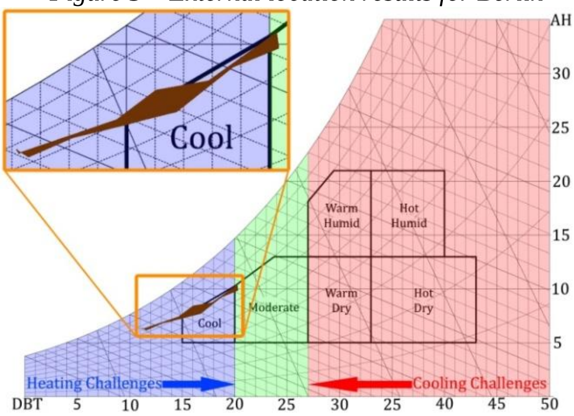

Figure 6 – External location results for Wellington

Figure 7 illustrates that Melbourne is predominantly below and in the cold climate zone, and partially in the moderate climate zone. Even though Melbourne's temperatures and humidities are in the moderate zone for a large proportion of the year, it is classified as a cold climate and buildings would have heating challenges.

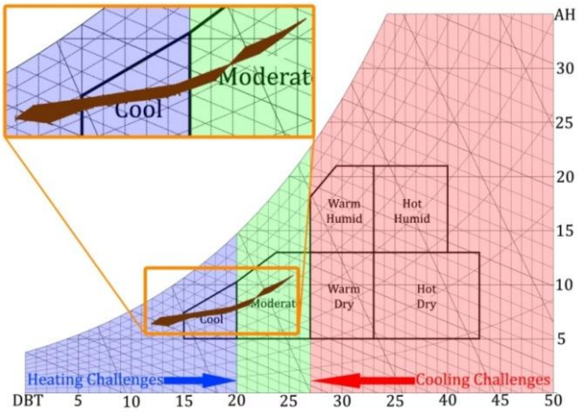

Figure 7 – External location results for Melbourne

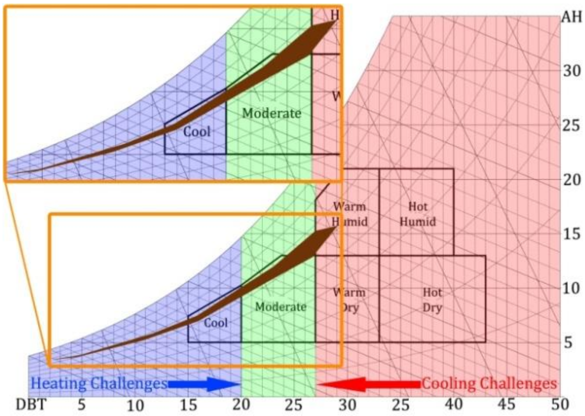

Figure 8 – External location results for New York

Figure 8 shows New York having temperatures and humidities ranging from below the cold zone to the warm humid climate zone. This means the location is zoned as a mixed cold and warm climate, and buildings would have both heating and cooling challenges.

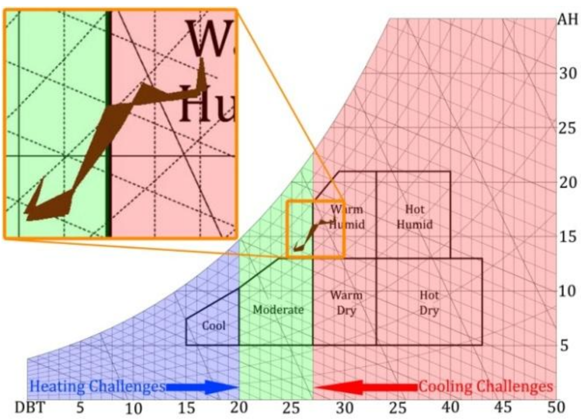

Figure 9 – External location results for Hawaii

Figure 9 shows that Kaneohe Bay, Hawaii is above the moderate zone and in the warm humid climate zone. It is categorised as a warm humid climate and would have cooling challenges.

The majority of these traditional climate zonings do not match the climate challenge labels identified by the IEA research experts. The two locations that do match are New York and Hawaii. This suggests that 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 a 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 provide general lessons for design in a climate.

Building Climate Classification Method

Figure 10 and 11 displays the simulated annual energy use, heat gains and heat losses for all seven climates. The heating energy use (red), solar gains (yellow), and internal heat gains (orange) are 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) are negative losses. Figure 10 compares the 100m^2 residential and 100m^2 non-residential reference building results. Figure 11 displays the results of the 1000m^2 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 100m2 and 1000m2 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.

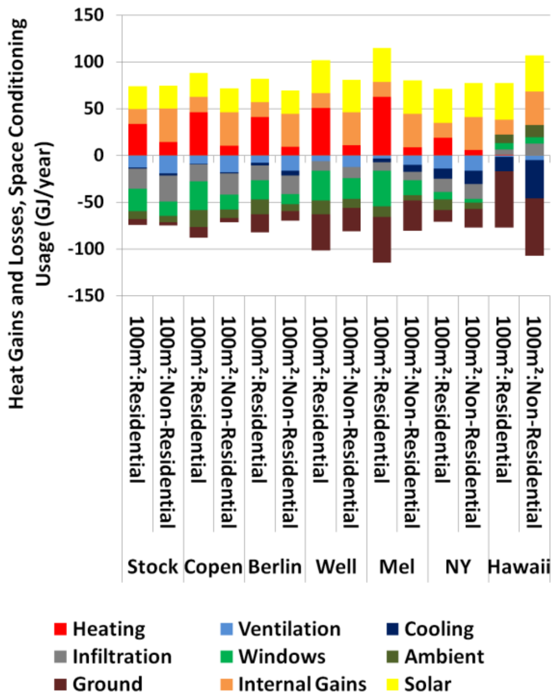

Figure 10 – Annual Internal heat gain and losses in the 100m^2 reference buildings

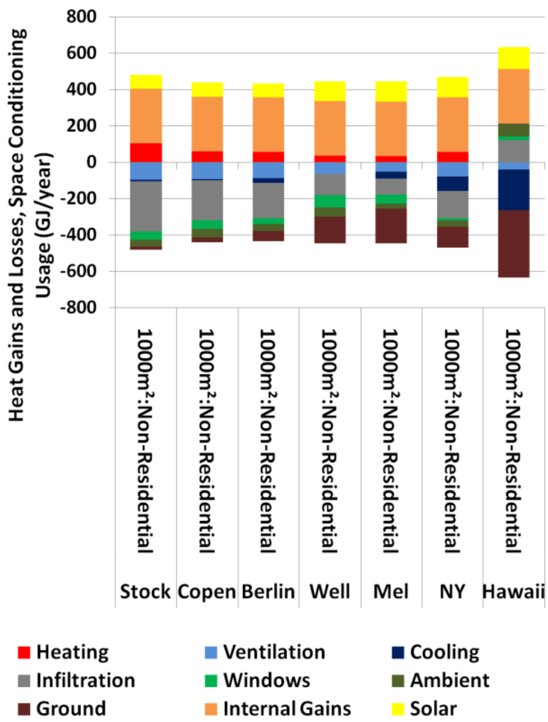

Figure 11 – Annual Internal heat gain and losses in the 1000m^2 non-residential reference building

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.

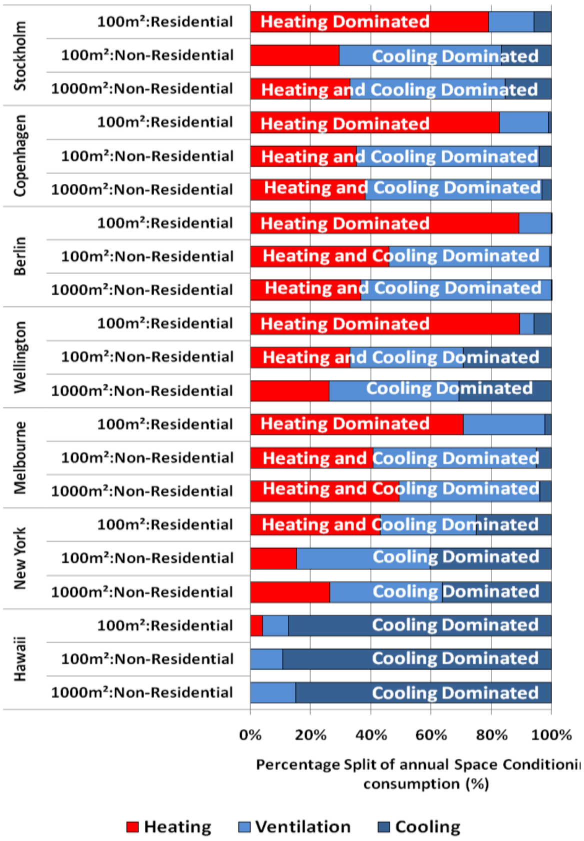

Figure 12 - Percentage split of the annual space conditioning usage for the three reference buildings

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 process 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^2 buildings is due to the number of people, lights and internal equipment. It can be seen that some of the 1000m^2 non-residential reference buildings dominant space conditioning process is different when compared to the 100m^2 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 traditional climate classification zones correspond to the three building climate classification zones by making the climate challenges the dominant space conditioning process. For example, Stockholm is a cold climate and has heating challenges and this corresponds to a heating dominated climate.

21 scenarios have been classified. 9 out of the 21 scenarios were placed in the same traditional external climate 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 12 scenarios all have differing traditional external climate zones from the building climate classification zones. All of the 12 buildings are the non-residential reference buildings in cold, and mixed cold and warm climates. The difference in climate zones is due to the increase in internal loads. This factor reduces the need for cooling drastically. 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 challenges: 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 classifications.

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 most likely 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.

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