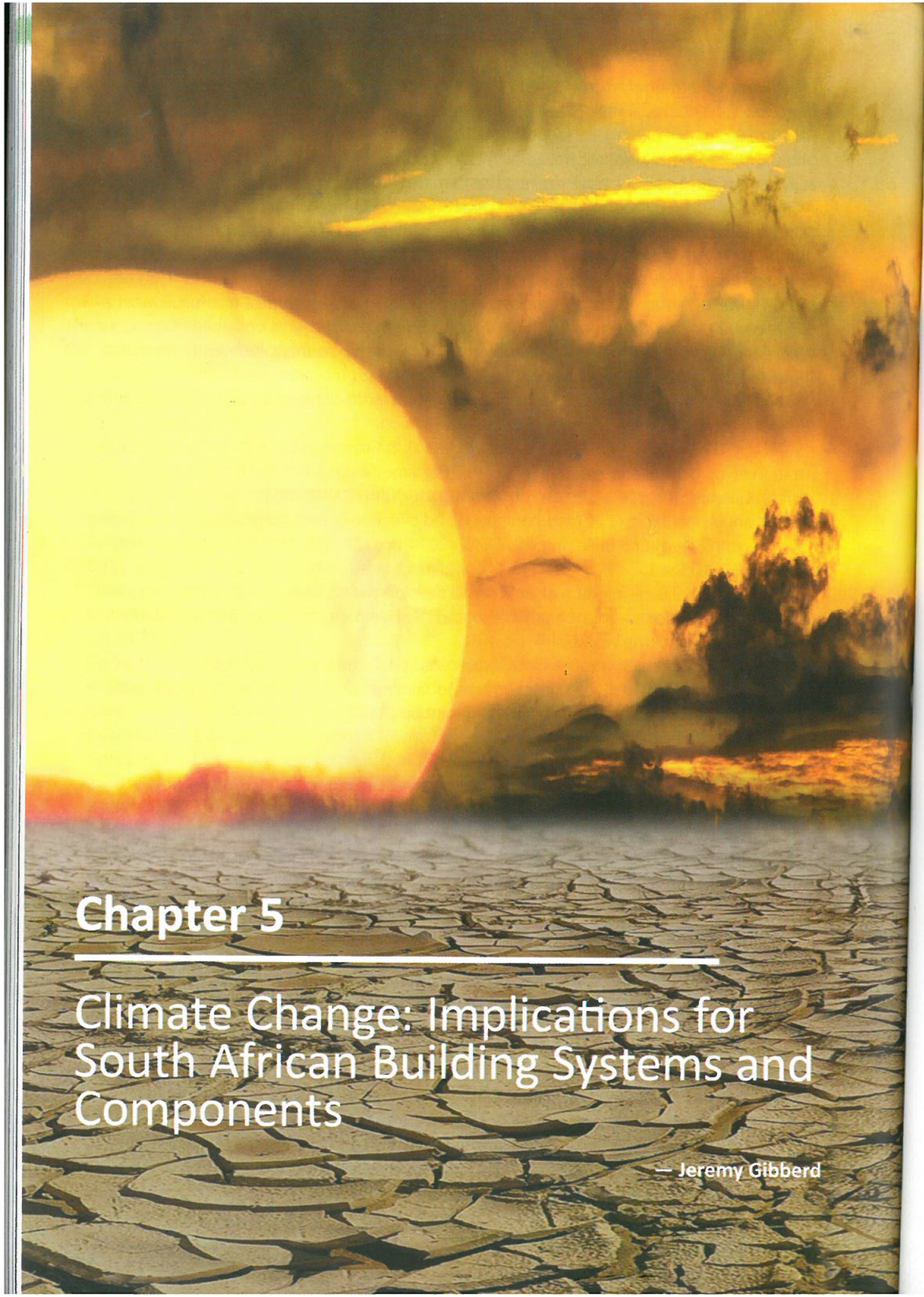

Chapter 5

Climate Change: Implications for South African Building Systems and Components

— Jeremy Gibberd

Introduction

Despite increasing awareness of climate change, there is little evidence of this being addressed in built environments in South Africa. Events such as flooding in Houston, USA, landslides in Free Town, Sierra Leone, and water shortages in La Paz, Bolivia and Cape Town in South Africa in 2017 demonstrate that it is increasingly urgent that built environments that are resilient to climate change impacts must be developed.

This chapter introduces climate change projections for South Africa and begins to determine the implications of these changes for buildings. Proposals are made on how buildings may be adapted to climate change and recommendations on further research and development are outlined.

Methodology

Climate change projections are subject to uncertainty (Müller et al, 2014). Modelling methodologies and assumptions also vary and can be complex (Hewitson and Crane, 2006; Müller et al, 2014; Engelbrecht, 2016). Therefore while the range of modelling approaches are acknowledged, this study is based on one projection and scenario in order to focus on built environment implications of climate change.

The climate change projection selected for the study was carried out in 2017 and provides a high level of detail (8 x 8 km resolution) (Engelbrecht, 2016). The scenario selected is a low mitigation scenario (RCP 8.5) for the period 2021 – 2050 relative to 1961-1990. Representative Concentration Pathways (RPCs) are defined according to their contribution to atmospheric radiative forcing in the year 2100 relative to pre-industrial values. A RCP 8.5 therefore represents the addition to the earth's radiation budget as a result of an increase in GHGs of +8.5 W/m2. This scenario is presented in figures in the main body of the study.

Implications of climate change for built environments are ascertained through an analysis of projections in different regions. Measures to address climate change are identified through a literature review. Examples provided in the study are drawn from residential, health and education sectors as these are some of the most vulnerable to climate change.

Climate change

Climate change is now considered as one of the most important global issues facing the world today and increasingly sophisticated climate models are being developed to project climate changes (Hamin and Gurran, 2009; Guan, 2009).

Designing climate-resilient architecture requires an understanding the climate change projections at the building site. As buildings usually have a lifespan of at least 50 years, these projections need to cover the next 50 years (Guan, 2009).

Climate change projections for South Africa have been generated for 2030, 2050 and 2100. This indicate that while there a significant differences across South Africa, some broad trends can be described:

- Hotter temperatures: Temperature increases of 1 to 2.5°C in the southern coastal areas and 3°C in the northern areas of South Africa are projected for the period 2021 to 2050, relative to temperatures in the period 1961 – 1990.
- Minimum temperatures: Minimum temperatures are projected to increase by 2 to 3 °C for the period 2021 – 2050, relative to the period 1961 -1990.
- Very hot days: An increase in very hot days is projected for the period 2021 – 2050, relative to 1961 – 1990.
- Changes in rainfall: Increases in annual rainfall are projected in the central interior and east coast, while reductions are expected in the western interior and the north-eastern parts of South Africa in the period 2021-2050, relative to the period 1971 – 2000.
- Extreme rainfall events: Extreme rainfall events are projected to increase in

frequency in the central interior and east coast for the period 2021-2050, relative to the period 1961 – 2000. For the period 2070-2099, relative to the period 1961 – 2000, reductions in these events are projected for Lesotho and Kwa-Zulu Natal Midlands areas.

- Increased wind speeds: Wind speeds are projected to increase in the northern interior regions of South Africa and decrease in other regions for the period 2021-2050, relative to the period 1961 – 2000 (Engelbrecht, 2016).

The implications of climate change for buildings

Better understanding of climate change implies a corresponding improvements in built environment responses. Addressing climate change in buildings requires a balance between mitigation and adaption strategies. Climate change mitigation strategies aim to reduce current and future greenhouse gas emissions in order to slow down and ultimately stop climate change. Climate change adaptation strategies aim to adjust to unavoidable changes that will in occur and minimize their negative impacts (Hamin and Gurran, 2009; IPCC, 2007)

These strategies can be in conflict. For instance, building adaptations to cope with increased wind speeds, storms and floods predicted by climate change projections may require additional materials and structure which have additional carbon emissions associated with their manufacturing and construction, thereby contributing to climate change. However synergies can be found. For examples, shifting to decentralized renewable energy generation reduces both carbon emissions (mitigation) as well as the risk of widespread power outages associated with severe storms (adaptation) (Hamin and Gurran, 2009). Where possible, this type of 'win-win' approach must be pursued.

In proposing measures to address climate change, uncertainties associated with projection models should be acknowledged. Proposals should, therefore, aim to yield benefits even in the absence of, or delay in, climate change (no regret), be adaptable and have margins that account for uncertainty (Hallegatte, 2009)

The capacity to adapt to future climate change is referred to as resilience. Resilience describes the ability to accommodate or adapt to, changes associated with climate change (Hamin and Gurran, 2009). The International Panel on Climate Change describes resilience as the capacity to absorb disturbance and change, while still retaining the same basic structure and functioning (IPCC, 2007). This implies an increased emphasis on flexibility and adaptability in building system and component design (IPCC, 2007). Research in this area has interesting implications for buildings and can provide designers with a rich palette of tools to develop more resilient buildings, systems and components (Gibberd, 2017; Gibberd 2017a).

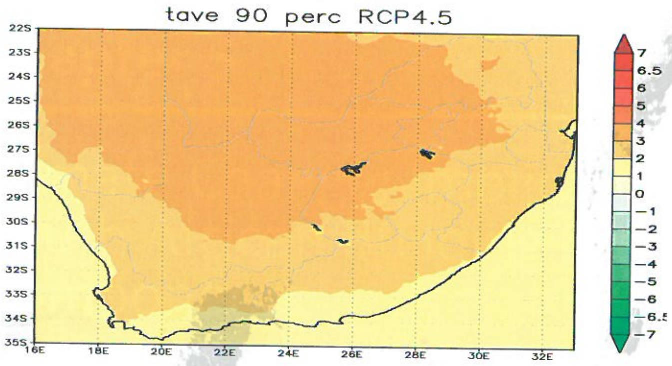

Figure 1. Projected change in the annual average temperature (°C) over South Africa at 8 km resolution, for 2021-2050 relative to 1961-1990 for a low mitigation scenario (RCP8.5) (Engelbrecht, 2016).

Higher average temperatures

Temperature increases of 1 to 2.5°C in the southern coastal areas and 3°C in the northern areas of South Africa are expected for the period 2021 to 2050, relative to temperatures in the period 1961 – 1990. This trend continues in the period 2070 to 2099 and average temperatures are projected to increase by a further 2 - 3°C over the southern coastal regions, with the increases of 4°C up to 7°C projected for the interior (Engelbrecht, 2016). Figure 1 shows these increases in annual average temperature for the period 2021-2050 relative to 1961 - 1990.

Higher average temperatures will result in temperatures within unconditioned buildings increasing. In particular, this effect will be experienced most acutely in buildings that have limited or no insulation and cooling systems, such as school buildings, clinics and low-cost housing (Gibberd and Motsatsi, 2013). Environments around buildings will also become hotter. This will affect conditions for people who work outside such as construction and agricultural workers. It will also affect children who play and exercise outside during school breaks and during school sports activities.

A range of implications of higher average temperatures can be envisaged for buildings, building systems and components. Higher temperatures will mean that aspects of existing and proposed designs may no longer be suitable. Increased temperatures will result in existing cooling equipment struggling to accommodate higher heat loads. Insufficient solar control, insulation and passive cooling strategies will mean that internal conditions in buildings become uncomfortably hot. Higher temperatures will also affect the lifespan of components and materials that have been designed and manufactured for lower ambient temperatures.

Addressing these implications is complex and should take into account detailed climate projections and local circumstances. The following generic measures may be considered to address increased average temperatures:

- External hard surfaces: The extent of external hard surfaces around buildings should be minimised. If this is unavoidable, lighter coloured materials should be used. This will help reduce the extent to which heat is absorbed and accumulates in urban spaces to produce what is known as the urban heat island effect (Zuo et al, 2014; Santamouris, 2015)
- Trees and shading: Shading should be provided around buildings and in areas where external spaces are occupied, such as school playgrounds. This reduces temperatures around buildings and provides cooler external spaces that can be used on hot days (Zuo et al, 2014; Wong & Chen, 2009).
- Cool roofs: Specifying lighter colours on external faces of roofs and walls can be used to reduce the heat absorption through these surfaces and therefore heat gain in the building (Cotana et al, 2014).
- Insulation: Increasing insulation in the building envelope reduces heat gains in buildings. In conditioned buildings, additional insulation throughout the building envelope can help reduce heat gain. In passive buildings, additional insulation can be used in the roof and applied selectively to the building envelope to reduce heat gains and improve the effectiveness of passive strategies (Saman et al, 2013).
- Passive cooling: Passive cooling refers the cooling of buildings to improve the indoor thermal comfort with low or no energy consumption and associated carbon emissions. Passive cooling strategies include cross ventilation, evaporative cooling and

night-time cooling. Cross ventilation is suitable for locations with breezes, such coastal regions, whereas night-time cooling is suitable for locations with high diurnal ranges, such as the interior of the country (Karimpour et al, 2015; Peacock et al, 2010).

- Mechanical cooling: Mechanical cooling systems can also be used to reduce temperatures in buildings. In housing, clinics and schools, ceiling fans powered by photovoltaic panels may be an effective means of introducing cooling at low cost while minimising associated carbon emissions.

Very hot days

Very hot days are defined as days when the maximum temperature exceeds 35°C. For the period 2021 – 2050 relative to 1961 – 1990 very hot days are projected to increase by 40 to 60 days per year in areas of the Limpopo valley. This will be higher in northern parts of the Northern Cape and North West provinces, where the increases may be up to 70 days per year. During the period 2070 – 2099 very hot days are projected to increase to 80 or more days per year for the entire northern and western interior of the South Africa (Engelbrecht, 2016). Figure 2 shows projected change in the number of very hot days for the period 2021-2050 relative to 1961 - 1990.

A range of implications of very hot days can be envisaged for buildings, building systems and components. Very hot days mean that existing cooling equipment in buildings may not be able to accommodate increased heat loads, especially when hot days occur consecutively. In buildings with insufficient insulation and inadequate passive cooling strategies, internal conditions in buildings will become uncomfortably hot (Gibberd and Motsatsi, 2013). Very hot conditions over long periods may also affect the lifespan of components and materials that have been designed for cooler temperatures.

Accommodating very hot days in buildings is complex and should take into account detailed climate projections and local circumstances. In the first instance, the measures described for increased average temperatures (above) may be used to address hotter conditions. However, on very hot days, the following measures related building and personal adaptation can be implemented:

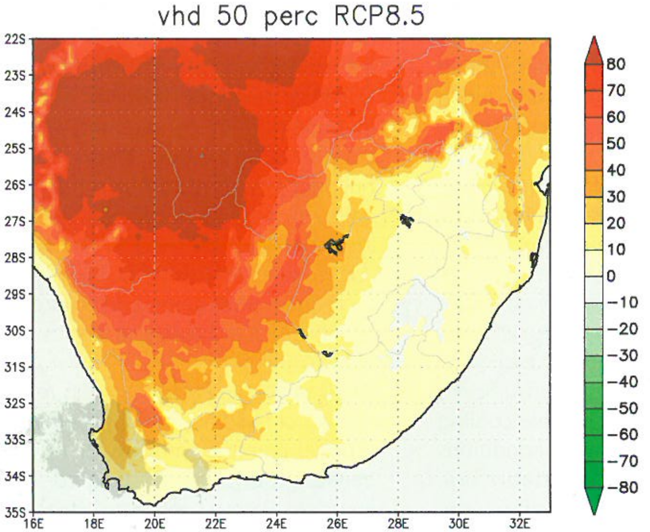

Figure 2. Projected change in the annual average number of very hot days (units are days per grid point per year) over South Africa at 8 km resolution, for 2021-2050 relative to 1961-1990 for a low mitigation scenario (RCP8.5) (Engelbrecht, 2016).

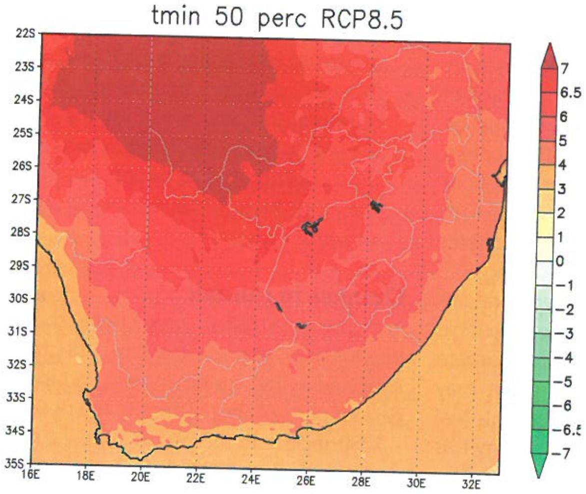

Figure 3. Projected change in the annual average minimum temperature (°C) over South Africa at 8 km resolution, for 2021-2050 relative to 1961-1990 for a low mitigation scenario (RCP8.5) (Engelbrecht, 2016).

- Building adaptations: Building adaptations to reduce heat stress include the provision of drinking water points, shading of all glazing in building envelopes, the provision of spaces around the buildings such as interior rooms, courtyards and rooftops which can be moved between to provide cooler spaces at different times of the day and night (Hatvani-Kovacs et al, 2016; Baker & Standeven, 1996).
- Personal adaptations: Personal adaptation to reduce heat dress include drinking water, spending more time indoors or in shaded areas, wearing loose clothing and planning the day to stay out of the heat and to move between cooler parts of the building (Krecar et al, 2014; Hatvani-Kovacs et al, 2016; Saman et al, 2013)

Minimum temperatures

Minimum temperatures are projected to increase by 2 to 3°C for the period 2021 – 2050, relative to the period 1961-1990. For the period 2071 to 2099 minimum temperatures are projected to an increase of more than 4°C in much of the interior with areas of the northern interior potentially experiencing increases exceeding 7°C. Figure 3 shows projected change in annual average minimum temperatures for the period 2021-2050 compared to the period 1961-1990.

Increasing minimum temperatures will result in reduced risk of very cold temperatures in buildings. The potential for water freezing in pipes and dangerous icy conditions on external surfaces will also be reduced. Increasing minimum temperatures will reduce the effectiveness of night-time cooling as a passive environmental control strategy in buildings.

However, higher minimum temperatures will also reduce heating loads for mechanical heating systems in buildings and mean that the requirement for heating is reduced or even eliminated in some locations. Indoor temperatures in buildings without insulation and inadequate passive heating strategies will be higher in winter, resulting in improved levels of comfort in winter.

Higher minimum temperatures mean that winter performance requirements of building components and equipment will be reduced. Therefore, there may be reduced performance requirements for systems and equipment designed to cater for cold and extremely cold conditions such as heating systems, insulation, double or triple glazing, and thermally broken window and door frames. However, it should be noted that some of these systems and equipment also help reduce heat gain under hot conditions and therefore may be appropriate for adapting to very hot days. Increasing minimum temperatures have the following implications for buildings:

- Insulation: Increasing minimum temperatures mean that it is easier to achieve comfortable internal conditions during winter. Climate change, however, may mean that it may also be more difficult to keep internal conditions comfortable during summer as higher temperatures are experienced. This will change the way insulation is designed and specified in order to cater for increased minimum temperatures, increased average temperatures and very hot days. A responsive approach which takes into account local circumstances and thermal mass rather than a 'blanket' approach in the application of insulation (which may lead to overheating) is likely to lead to the best results (Gibberd, 2009; Porritt et al, 2013; Ren et al, 2014).
- Heating: Heating requirements are likely to be reduced with increasing minimum temperatures. However, increased average temperatures will also result in increasing cooling requirements. This shift will need to be addressed in the design and specification of heating and cooling equipment.
- Passive design: Increased minimum temperatures will result in the reduced cooling potential of strategies such as night-time cooling. Passive design strategies will, therefore, need to be revised for projected climates.

Changes in rainfall

Increases in rainfall are projected in the central interior and east coast, while reductions are expected in the western interior and the north-eastern parts of South Africa in the period 2021 – 2050, relative to the period 1971 – 2000. Over the period 2070 to 2099 relative to the period 1961 to 1990 rainfall projections are expected to follow a similar pattern to the earlier period, however, there is also a possibility that rainfall decreases over the central interior and east coast of South Africa. Figure 4 shows changes in annual average rainfall for the period 2021 – 2050 compared to 1961 – 1990.

Reductions and increases in annual rainfall have a number of implications for buildings, building systems and component. Reductions in rainfall in cities and settlements will mean that these will be more likely to be affected by water shortages as water supplies from dams, rivers and boreholes are more likely to be depleted.

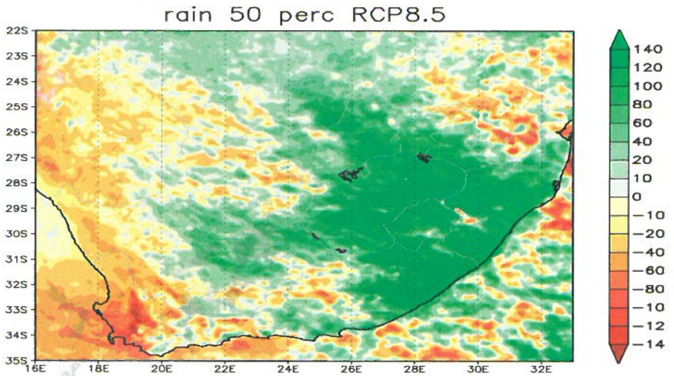

Figure 4. Projected change in in the annual average rainfall totals (mm) over South Africa at 8 km resolution, for 2021-2050 relative to 1961-1990 for a low mitigation scenario (RCP8.5) (Engelbrecht, 2016).

Reductions in rainfall will diminish the moisture available for plants and therefore influence the type of plants that will grow leading to the establishment of more drought-resistant species.

More rainfall will increase moisture around buildings. This will result in increased dampness and moisture-related problems in poorly constructed buildings and buildings with insufficient damp and water proofing. Where not addressed, these problems can lead to rapid deterioration of the building fabric and health problems, such as asthma (Bornehag et al, 2004; Fisk et al, 2007). Wetter conditions also favour different species and lead to changes in the type of plants and trees that will thrive in particular environments.

The following generic building adaptations can be applied to address changes in annual rainfall:

Areas with decreasing annual rainfall

- Water efficient fittings: Highly efficient water fittings such as low-flow showerheads and taps should be used to reduce water consumption (Gibberd 2009a). This can be complemented by water metering and leak detection systems that ensure that water consumption is monitored and consumption reduced.
- The use of water: Water uses that are not strictly necessary should be discouraged. Examples include baths (showers should be used instead), swimming pools and large ornamental lawns and ponds. In highly water-stressed areas alternatives to the use of water to flush toilets and to wash objects such as cars should be investigated. In these cases, dry sanitation and dry cleaning methods may be appropriate (Gibberd, 2009a).
- Grey water systems: Grey water systems can significantly reduce water consumption in building types where grey water from activities such as hand washing and showers is available in adequate quantities. Grey water can be used to flush toilets or irrigate plants, reducing or avoiding the use of mains potable water for these purposes (Gibberd, 2009a).
- Rainwater harvesting: Increased use of rainwater harvesting systems can be used to store rainwater enabling this to be available during dry periods (Gibberd 2009a, Gibberd 2015). This reduces the pressure on mains water supplies and provides a buffer in case of water shortages.
- Planting schemes and landscaping: Specification of plants, such as trees, with a higher tolerance for drier conditions, will ensure that these survive drier conditions. Water-scarce landscaping management techniques such as mulching and planting species that have the same water requirements together (hydro zoning) will help plants grow in drier conditions.

Areas with increasing annual rainfall

- Water proofing details: To avoid potential dampness and moisture-related problems in buildings, increased attention to waterproofing in buildings will be required. This includes ensuring that the correct damp-proof membrane (DPM) and damp-proof course (DPC) products are used and that these are installed correctly. In addition, additional care will be required to ensure that roofs and exposed parts of the building are water tight and leaks are avoided. This means careful selection and specification of components, construction by trained contractors and effective supervision and testing of completed installations.
- Sustainable Urban Drainage Systems (SUDS): Increasing annual rainfall will heighten the risk of flooding in urban areas. This can be addressed by reducing the extent of impervious surfaces in urban areas and increasing areas of gardens and planted beds where runoff can be directed and absorbed. Components, such as permeable paving, can also be used to allow runoff to

replenish groundwater or be stored and used for irrigation and other purposes. Storm water can be reduced from sites through landscaping techniques which use filter strips, swales, and ponds to retain and store runoff on site.

Extreme rainfall events

Extreme rainfall events are defined as events when 20mm of rain occurs over an area of 64km2 over 24 hours. Over the period 2021 to 2050 relative to 1961 – 2000 the number of extreme rainfall events is projected to increase in the interior of South Africa. However, over the period 2070 to 2099, the number of extreme rainfall events is projected to decrease. Figure 5 shows these changes for the period 2021-2050 relative to 1961 - 1990.

Projected increases in extreme rainfall days have a number of implications for buildings. Vey heavy rainfall on roofs, if not disposed of quickly, can damage rainwater goods, roofs and cause structural collapse. Storm water can also accumulate leading to flooding of low lying buildings and infrastructure.

Buildings can be adapted for extreme rainfall. These can include measures forincreased annual rainfall (as above) as well as the following for more extreme rainfall:

- Roof design and details: Roofs and rainwater goods have to be specifically designed for projected rainfall events. This may mean revising rainwater system designs to provide for larger volumes of water and include higher capacity and more numerous outlets, gutters and downpipes. In addition, similar considerations will be required to ensure that increased volumes of rainwater generated can be stored or disposed of safely.
- Storm water design: Extreme rainfall events will substantially increase volumes of surface runoff and the potential for flooding. This can be addressed by controlling the area of surfaces generating runoff and by ensuring appropriate means, such as retention and detention ponds, are in place and capable of managing runoff volumes.
- Flooding: In buildings in low lying areas where flooding is possible a number adaptations can be considered. Ground floor levels can be raised to reduce or avoid flooding the interior of buildings. Building layouts can be designed to ensure that water flows around and away from buildings and that 'damming' that may cause structural collapse is prevented. The design and maintenance of storm water drainage systems should ensure that blockages caused by detritus that can cause flooding is avoided. Expensive or delicate equipment and goods may be located higher up in buildings to reduce the possibility that this is damaged by flooding. In addition, building materials that are less prone to damage by moisture and flooding may be specified to avoid the need for large-scale replacement of components and elements in the building when flooding occurs.

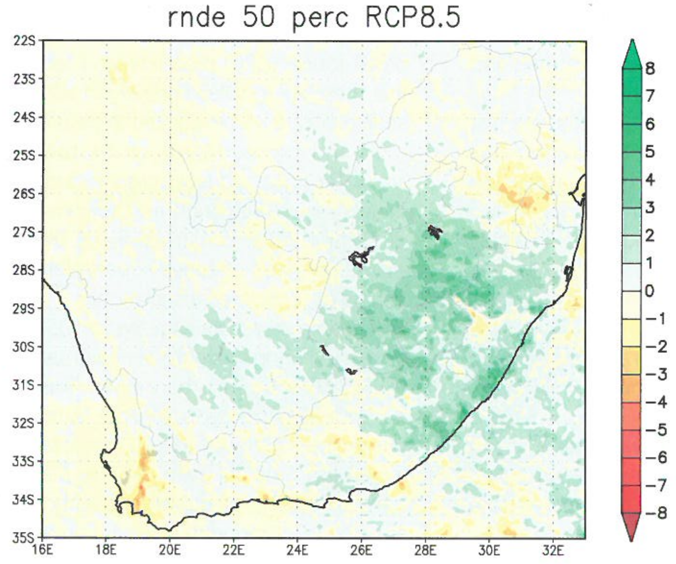

Figure 5. Projected change in the annual average number of extreme rainfall days (units are numbers of grid points per year) over South Africa at 8 km resolution, for 2021-2050 relative to 1961-1990 for a low mitigation scenario (RCP8.5) (Engelbrecht, 2016).

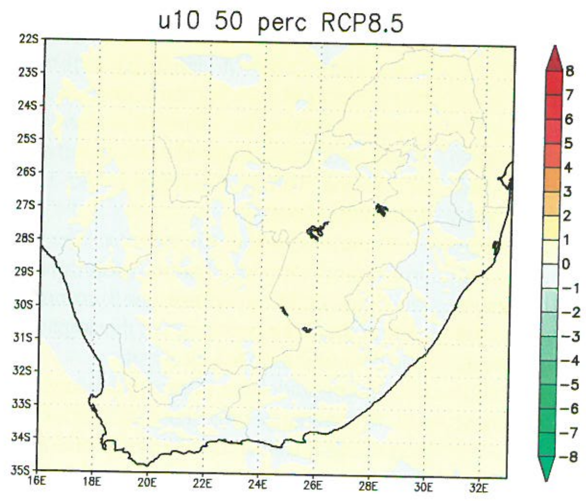

Figure 6. Projected change in the annual average wind speed (m/s) over South Africa at 8 km resolution, for 2021-2050 relative to 1961-1990 for a low mitigation scenario (RCP8.5) (Engelbrecht, 2016).

Increased wind speeds

For the period 2021 to 2050 relative to 1961 to 1990 increased wind speeds are projected along the east coast and over high altitude areas of the southwestern Cape as well as the eastern and southern escarpment. Wind speeds in the southern interior are projected to decrease, while they are projected to increase in the northern interior. Figure 6 shows the projected changes in annual average wind speeds changes for the period 2021-2050 relative to 1961 - 1990.

Projected increases in average wind speeds have a number of implications for buildings. Increased wind speeds result in additional stress on exposed elements such as towers and overhanging sections of roof. If not catered for in design and construction, this additional stress can result in damage, such as roof sheeting becoming detached. Changes in wind speed will also affect energy generation potential in wind turbines.

Buildings can be adapted to address projected changes in wind speeds in the following way:

Wind loadings: Further investigation of projected wind speeds should be carried out. If these show that there are likely to be substantial increases, guidance on wind loadings in buildings should be reviewed and revised if necessary. Aspects that may be affected include guidance on wind loading in roofs, walls and large areas of glazing. Adaptations may include additional structural and fixing elements to compensate for increased loadings.

Conclusions and recommendations

Projections for South African indicate that there will be significant changes in climate over the period 2021 – 2099 relative to the period 1961-1990. These changes include higher average temperatures, higher minimum temperatures, increases in the number of very hot days, changes in rainfall, increases in extreme rainfall events, and changes in average wind speeds. There are significant implications for buildings and building systems and components of these changes.

As buildings are generally designed to be used for at least 50 years it is important that buildings, and their systems and components, are designed to accommodate projected changes that may occur over their lifespan. Climate change has meant that many aspects of buildings have to be reconsidered and new approaches, systems and components have to be developed. A selection of initial considerations is discussed.

The current onset of climate change means that building, building systems and component designs need to be urgently reviewed, and where necessarily, adapted to changing climate conditions. This can be supported by the following actions:

Climate change projections: The most important climate change projections for building, building systems and component design should be developed so that implications can be understood at a local level.

Design guidelines: Design guidelines based on climate change projections should be created to provide guidance on the design of buildings, building systems and components. Current standards and regulations: Current building, building system and component standards and regulations should be reviewed and adapted as necessary in the light of climate change projections.

References

- Baker, N. and Standeven, M., 1996. Thermal comfort for free-running buildings. Energy and Buildings, 23(3), pp.175-182.
- Bornehag, C.G., Sundell, J., Bonini, S., Custovic, A., Malmberg, P., Skerfving, S., Sigsgaard, T. and Verhoeff, A., 2004. Dampness in buildings as a risk factor for health effects, EUROEXPO: a multidisciplinary review of the literature (1998–2000) on dampness and mite exposure in buildings and health effects. Indoor air, 14(4), pp.243-257.
- Cotana, F., Rossi, F., Filipponi, M., Coccia, V., Pisello, A.L., Bonamente, E., Petrozzi, A. and Cavalaglio, G., 2014. Albedo control as an effective strategy to tackle Global Warming: A case study. Applied Energy, 130, pp.641-647.
- Engelbrecht, F., 2017. Detailed projections of future climate change over South Africa, CSIR Technical Report.
- Fisk, W.J., Lei-Gomez, Q. and Mendell, M.J., 2007. Meta-analyses of the associations of respiratory health effects with dampness and mold in homes. Indoor air, 17(4), pp.284-296.
- Gibberd, J., and Motsatsi, L., 2013. Are Environmental Conditions in South African Classrooms Conducive for Learning?, SB13 Southern Africa, 15-16 October 2013, Cape Town, South Africa.
- Gibberd, J. 2009. Building Envelope, Chapter in the Green Building Handbook Volume 1, Alive 2 Green Publishers, ISBN 978-0-620-45067-6
- Gibberd, J. 2009a. Water Conservation, Chapter in the Green Building Handbook Volume 1, Alive 2 Green Publishers, ISBN 978-0-620-45067-6
- Gibberd, J., 2015. Rainwater harvesting playing a valuable role in increasing the resilience and sustainability of water supply, Sustainable Water Resource Handbook Volume 6, Alive 2 Green Publishers
- Gibberd, J., 2017. Social Resilience in Urban Areas, 11th Built Environment Conference, Durban South Africa, 6 – 8th August 2017 Durban, South Africa.
- Gibberd, J., 2017a. Water Resilience in Urban Areas, 11th Built Environment Conference, Durban South Africa, 6 – 8th August 2017 Durban, South Africa.
- Guan, L., 2009. Preparation of future weather data to study the impact of climate change on buildings. Building and environment, 44(4), pp.793-800.
- Hallegatte, S., 2009. Strategies to adapt to an uncertain climate change. Global environmental change, 19(2), pp.240-247.
- Hamin, E.M. and Gurran, N., 2009. Urban form and climate change: Balancing adaptation and mitigation in the US and Australia. Habitat international, 33(3), pp.238-245.
- Hatvani-Kovacs, G., Belusko, M., Skinner, N., Pockett, J. and Boland, J., 2016. Heat stress risk and resilience in the urban environment. Sustainable Cities and Society, 26, pp.278-288.
- Hewitson, B.C. and Crane, R.G., 2006. Consensus between GCM climate change projections with empirical downscaling: precipitation downscaling over South Africa. International Journal of Climatology, 26(10), pp.1315-1337.
- IPCC, 2007. Climate change 2007: Synthesis report, fourth assessment report. Cambridge: International Panel on Climate Change and Cambridge University Press.
- Karimpour, M., Belusko, M., Xing, K., Boland, J. and Bruno, F., 2015. Impact of climate change on the design of energy efficient residential building envelopes. Energy and Buildings, 87, pp.142-154.
- Ren, Z., Wang, X. and Chen, D., 2014. Heat stress within energy efficient dwellings in Australia. Architectural Science Review, 57(3), pp.227-236.
- Krecar, I.M., Kolega, M. and Kunac, Ş.F., 2014. The Effects of Drinking Water on Attention. Procedia-Social and Behavioral Sciences, 159, pp.577-583.
- Lapisa, R., Bozonnet, E., Abadie, M.O. and Salagnac, P., 2013. Cool roof and ventilation efficiency as passive cooling strategies for commercial low-rise buildings–ground thermal inertia impact. Advances in Building Energy Research, 7(2), pp.192-208.
- Müller, C., Waha, K., Bondeau, A. and Heinke, J., 2014. Hotspots of climate change impacts in sub-Saharan Africa and implications for adaptation and development. Global change biology, 20(8), pp.2505-2517.
- Peacock, A.D., Jenkins, D.P. and Kane, D., 2010. Investigating the potential of overheating in UK dwellings as a consequence of extant climate change. Energy policy, 38(7), pp.3277-3288.
- Porritt, S., C. Cropper, P., Shao, L. and I. Goodier, C., 2013. Heat wave adaptations for UK dwellings and development of a retrofit toolkit. International Journal of Disaster Resilience in the Built Environment, 4(3), pp.269-286.
- Saman, W., Boland, J., Pullen, S., de Dear, R.J., Soebarto, V., Miller, W.F., Pocock, B., Belusko, M., Bruno, F., Whaley, D. and Pockett, J., 2013. A framework for adaptation of Australian households to heat waves. National Climate Change Adaptation Research Facility.
- Santamouris, M., 2014. On the energy impact of urban heat island and global warming on buildings. Energy and Buildings, 82, pp.100-113.
- Wong, N.H. and Chen, Y., 2008. Tropical urban heat islands: climate, buildings and greenery. Routledge.
- Zuo, J., Pullen, S., Palmer, J., Bennetts, H., Chileshe, N. and Ma, T., 2015. Impacts of heat waves and corresponding measures: a review. Journal of Cleaner Production, 92, pp.1-12.