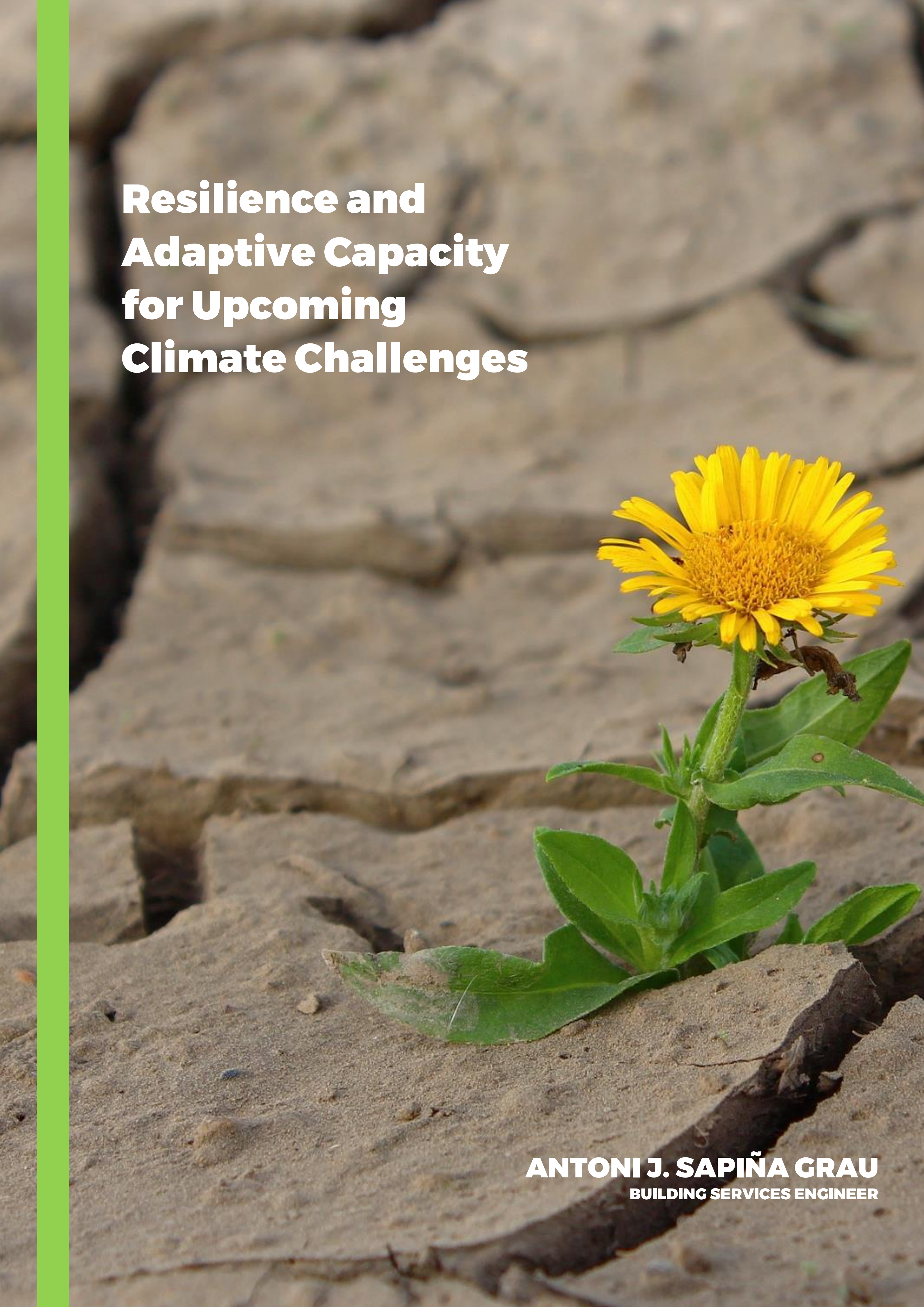
Resilience and Adaptive Capacity for Upcoming Climate Challenges



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1. INTRODUCTION

Building services designs are currently facing many restrictions and challenges every year, such as increased user comfort requirements, regulation updates and energy target However, one of the greatest future challenges is climate change. Climate change is more than a reality, as heat waves, flooding and heavy rainfall are not a future concern anymore: they have become current issues. Buildings must not only have a good energy performance in the present, but must also be able to adapt to future weather conditions.

Many disciplines and businesses have been investing a lot of time and effort to study climate change in order to develop mitigation solutions. The same is true for the building services industry, where there has been a lot of knowledge focused only on mitigation systems to reduce CO_2 emissions. However, there is a gap of knowledge on adaptation and resilience.

By considering building typology, location, climate and function, it is possible to prepare projects and clients to tackle the challenges of climate change. Engineers must combine the latest climate forecast data and sensible risk mitigation techniques to create buildings designed not only for the present, but also for future extreme weather conditions.

The following report will analyse this matter by identifying future concerns that climate change will impose to the building services market. Furthermore, it will highlight different energy adaptation strategies and resilience options to improve present and future building performance.

KEN DALE

The Ken Dale Travel Bursary was established by CIBSE to commemorate Ken Dale's contribution to the Institution and the Building Services profession. The Ken Dale Travel Bursary grants awards to CIBSE members in the developmental stage of their career who wish to spend three to four weeks outside their own country researching aspects related to their field of work and which will be of benefit to CIBSE, their employer, their clients and the profession.

The Bursary offers young building services engineers the opportunity to experience technical, economic, environmental, social and political conditions in another country, and to examine how these factors impact on the practice of building services engineering.

ABOUT THE AUTHOR

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Antoni J. Sapiña Grau works as a Building Services Engineer. For the last years, he has developed HVAC designs, implementing systems for energy saving applying sustainability criteria, as well as carrying out inspections to ensure optimal performance on the designs. He has been involved in projects in Spain, Mexico and the United Kingdom, implementing sustainability at the highest possible level to ensure best performance and reduction of CO_2 emissions.

Winner of Graduate of the Year in 2016, for the presentation on Problem Solving with Technology on the theme of 'Computers and Digital Technologies are Transforming the Way Engineers Work', and shortlisted as Engineer of the year in 2019.

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1.1. MITIGATION vs. ADAPTION

All buildings must reduce greenhouse gas emissions to a minimum to decrease the effect on climate. All the strategies for CO2 reduction are known as “mitigation strategies”.

However, the current scenario shows that some of the impacts of climate change cannot be avoided. Climate will change, and buildings and users will feel the consequences. That is why buildings must start to adapt and shape to the new outside scheme. Current designs must work in current and future weather to reduce their impact and guarantee a sustainable Earth.

The result of all these strategies is called “adaption”.

Designs must identify resilience factors at early stages to enable the design of strong building services against sudden situations. Resilient systems will allow the building to recover from unexpected situations. This will help the building’s performance, business and the users’ comfort and safety.

CONCEPT TO WATCH OUT FOR!

WHY ADAPTING?

Extreme weather will not only affect building performance: there will be many interconnected negative impacts. Loss of productivity in office spaces due to user discomfort, death among older people, ill health due to an increase of air pollutants, business losses due to failure in energy supply…

Building services should resist extreme events while providing essential services to the users within. Furthermore, the building must have the ability to return to normal performance operation after those events. The purpose of these designs is to enable adaptation and to improve the response to vulnerabilities and changing circumstances.

2. CLIMATE CHANGE

The first step is to analyse what climate is and how it affects building services. A research trip was undertaken over a period of four weeks. Each week was spent in a different country, visiting sites and meeting with relevant engineers involved in the schemes at differing stages.

The overarching aim of the research trip was to find out how to design resilient and adaptive systems against climate change. Following further research and conversations with experts in the field, it is important to highlight that climate change has reached a point from which it is not possible to go back. Now, it falls on all of us to reduce the consequences as much as possible and to make sure that buildings perform as energy-efficiently as possible and that CO_2 emissions are kept as low as possible.

Therefore, this research is aimed to meet with expert designers and consultants who factor climate change into their building services designs, to learn from their approach and to champion this best practice through best design. The following paper describes the challenges faced and lessons learned in order to apply this application in the UK.

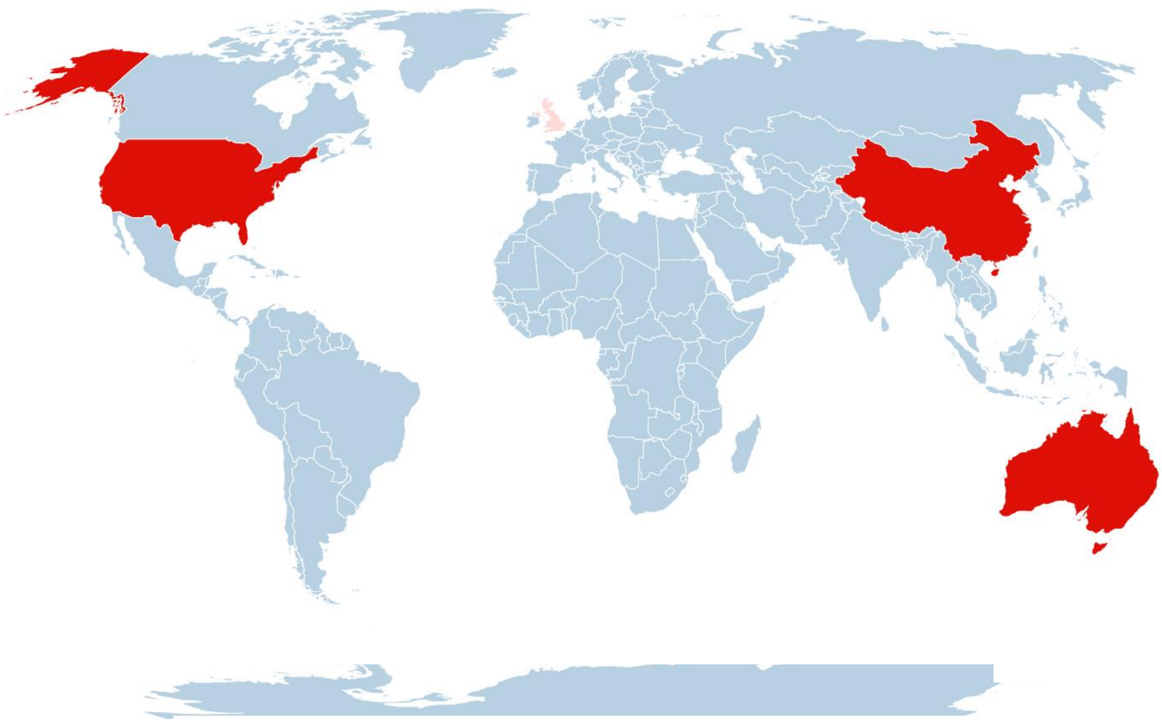
Research Questions

- What are the main risks to building services due to climate change?
- How can those risks be mitigated or avoided?

Methodology

- Visit consultancies and study projects located in different extreme climates.
- Understand resilience strategies employed in different projects and the reasons behind them.
- Prepare and specify all design best practice used in each part of the world related to climate change resilience.
- Offer all contributors an opportunity to provide feedback on the final report before publication.

Cities Visited: Shanghai, Hong Kong, Sydney, New York and Boston



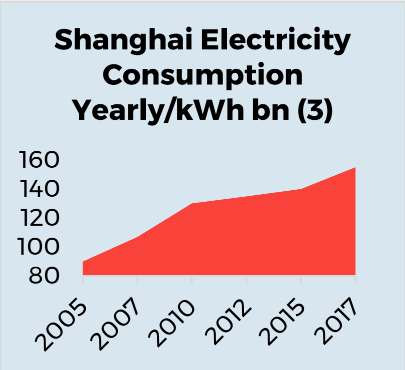
2.1. SHANGHAI

China is the fourth biggest country in the world. Due to its size, the country has different type of climate (1):

Global warming is perfectly shown in China. The average temperature and precipitation in the 2020s, 2050s and 2080s are expected to increase dramatically (2).

PERIOD	TEMPERATURE CHANGE (˚C)	PRECIPITATION CHANGE (%)
2020s	+1.3 ˚C	+5 %
2050s	+2.6 ˚C	+10 %
2070s	+4.5 ˚C	+17 %

As a reference of climate change in China, Shanghai is the best city to depict extreme weathers. Shanghai, west of the East China Sea and North of Hangzhou Bay, has a humid subtropical climate. Winters are very cold, sometimes reaching sub-zero temperatures. However, summers tend to be very hot and humid. The main issues building services must face in Shanghai are increasing temperature due to heat island effect, tropical cyclones and heavy rainfall.



The Shanghai Water Authority decided to spend 25 billion yuan (£270 million) to upgrade the municipal drainage system for flooding purposes.

It is the largest city in China in terms of population, which entails a great need for energy. Due to climate change and energy use trends, electricity consumption has increased during the past few years. By the end of the century, the rate of electrification in buildings will be about 60%.

Shanghai is in the HSCW (Hot Summers and Cold Winters) zone, where building services must adapt for both seasons. In terms of heating, there is a growing demand due to the increasing of living standards plus the cold weather. Now, new sources of heat, such as heat pumps and flexible indoor terminals, are being promoted to meet all seasons' requirements both in summer and winter time.

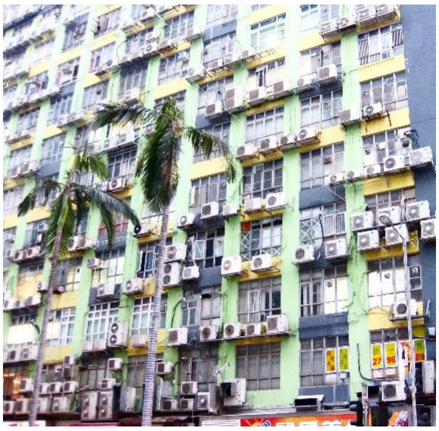
Cooling demand is increasing. The Chinese government is promoting a reduction in energy consumption by adapting lifestyle and systems. Solar water heating is used in many residential projects.

The government has established different type of policies to improve resiliency and mitigate climate change impact. Some of these policies are improving district heating, creating building energy codes, building energy-efficient labelling programmes and investing in retrofitting existing buildings.

The whole city has also been promoting the concept of green roofs in the area. The purpose of green roofs is to reduce rain runoff and the heat island effect. The main climate change programmes in Shanghai are LEED and Green Building Label. Green Building Label is a new labelling system created by the government to improve energy usage and reduce climate change impact. Depending on the system's criteria, buildings will be rated from one to three stars.

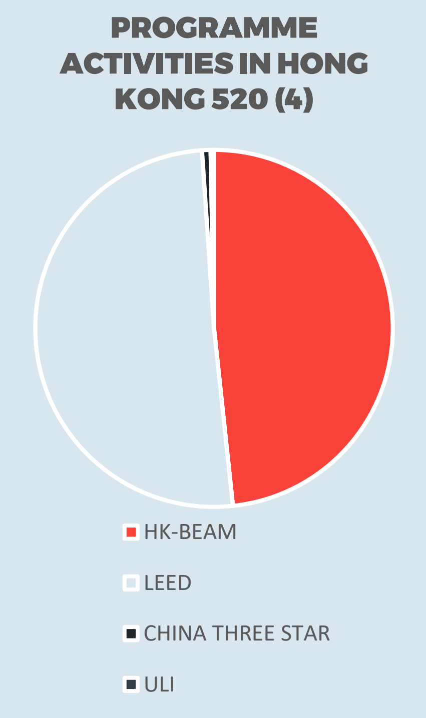
2.2. HONG KONG

Hong Kong has a subtropical climate. There is a winter monsoon that brings cold and dry air. Spring is short, and cloud cover means that sun radiation is at its lowest level. Furthermore, there is light rain and foggy and humid conditions. In summer, the weather is hot and humid with thunderstorms. Autumn is windy, with winds coming from an easterly direction. There is a big drop in cloud cover and humidity during this season.



Typical heat rejection units arrangement in Hong Kong

Eight high temperature records were broken in Hong Kong in 2017. The average winter temperature from December to February hovered at 18.4 degrees Celsius, 1.4 degrees higher than the 30-year normal reading. Every year, heatwaves increase heating gains in buildings, making the use of cooling rise to record levels (5)



Due to climate change, there is a big risk of damage to building basements and increased risk of rain penetration across building fabric. Both risks will affect building services, especially in cabling and pipes. In October 2018, the city suffered the strongest typhoon since 1904, a signal No 10: Typhoon Mangkhut.

Hong Kong has carried out a substantial amount of climate change adaptation due to the extreme weather the country faces every year.

(Xinhua News Agency) Office building damaged after Typoon Mangkhut

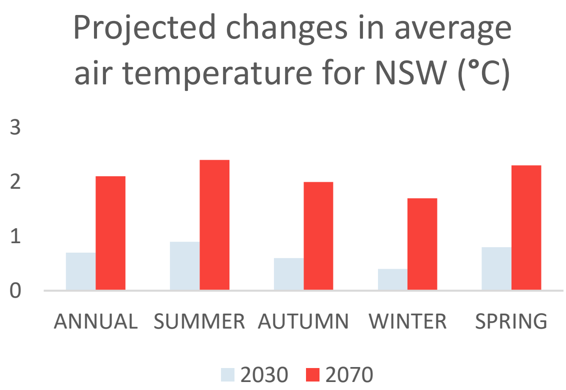
As a first step to a climate change solution, and to improve the performance of their buildings, they developed BEAM: Building Environmental Assessment Method.

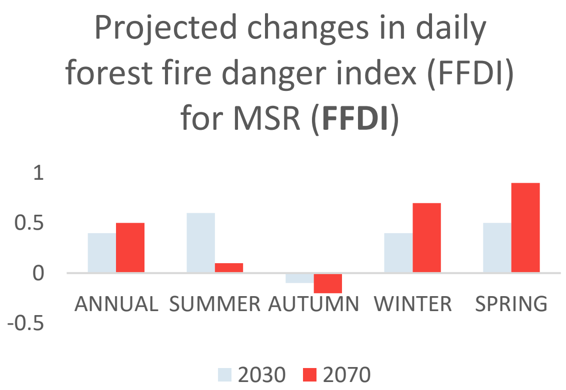
Its main purpose is to asses existing and new buildings with a range of good practices in planning, design, construction, management, operation and maintenance, and is aligned with local regulations, standards and codes of practice.

BEAM assessment and sustainability certification provides a safer, healthier, more comfortable, more functional and more efficient living or working environment for its users. It is a similar system to known systems such as LEED or BREEAM.

2.3. NEW SOUTH WALES - SYDNEY

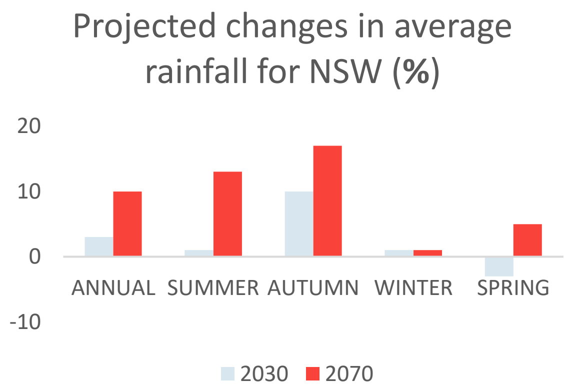
In recent years, Australia has suffered storms, floods bush fire and drought that have caused a lot of building damage due to extreme weather and loss of energy supply. (6)





New South Wales (NSW) is going to get warmer in the near (2030) and far (2070) future. The heating effect of global warming projects an average of 0.7C in the "near future," and 1.9C in the "far future," with an increase in the number of high-temperature days. The number of cold nights will decrease, which will affect the increasing temperatures during daytime.

The risk of bushfire is a key topic that has become more and more significant during the past few years. The combination of low rainfall in winter and heatwave in summer provided an environment for increase bushfire in Australia. These values are expected to increase in the near and far future.



Rainfall will decrease during spring and winter, and it will increase during summer and autumn, making the peak rains bigger and causing localised flooding.

As the graphs shows, the Australian climate is changing: higher temperatures, especially at night; rising sea-levels and increased flooding; increase of rainfall; and extreme weather effects.

The frequency of heat waves has been on the increase in Australia since 1950. Unfortunately, it is expected to keep rising. Heat waves has been estimated to cost the Australian economy about $6.9 billion AUD due to reduced productivity and absenteeism.

CSIRO and the NSW Office of Environment and Heritage have produced great amounts of information to anticipate climate change consequences.

The idea is to make users, society and businesses be aware of possible future scenarios and think ahead.

All the climate adaption plans are based on industry bodies initiatives. The state and local Gov are requesting CAP for new developments. But industry bodies such as insurance, infrastructure and sustainability are developing guidelines and tools to de-risk and reduce the impact of extreme weather events. The government is investing a lot of resources into developing legislation to cover this topic such as:

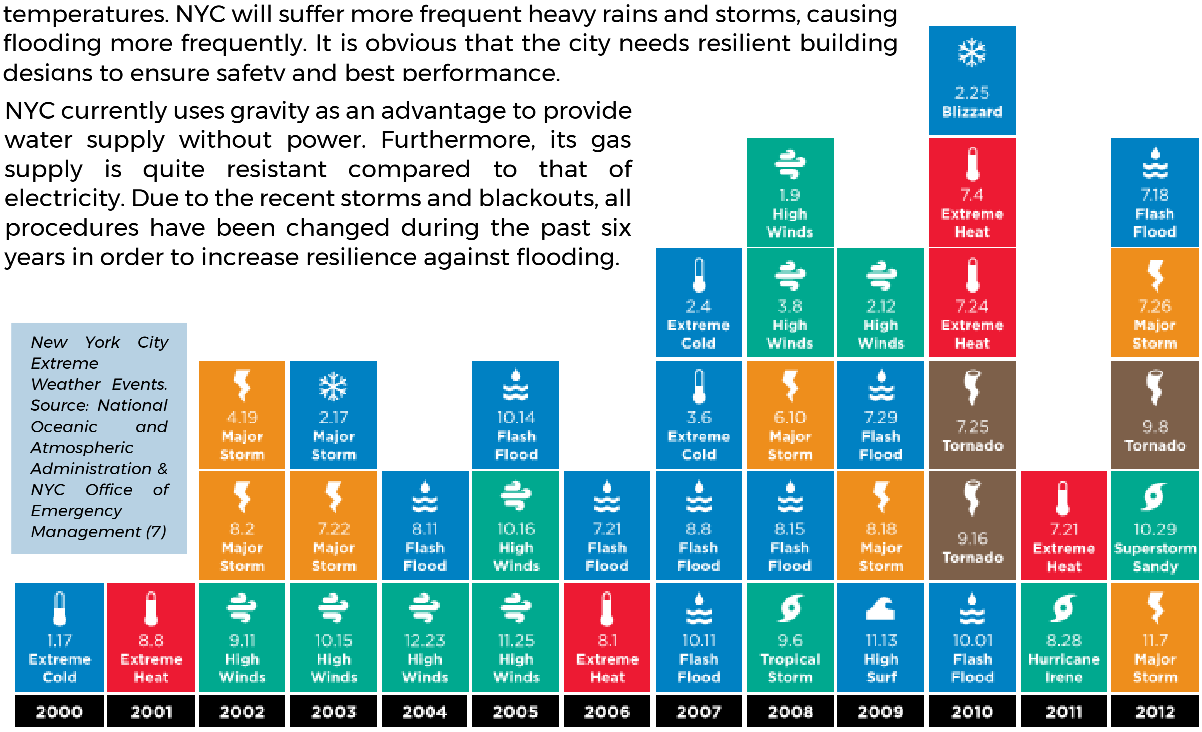
- Australian Standard AS 5334-2013 'Climate change adaptation for settlements and infrastructure'
- ISO 31000-2009 – Risk Management – Principles and Guidance (adopted in Australia and New Zealand as AS/NZS ISO 31000:2009)
- AGO, Climate Change Risks and Impacts: A Guide for Government and Business
- Australian Rainfall and Runoff (ARR) 2016 is a national guideline document
- Green Building Council of Australia

2.4. NORTHEAST COASTAL REGION: NEW YORK-BOSTON

In the past 20 years, New York City has suffered nine coastal storms and six heat waves. Due to climate change, there have been widespread power failures in the whole city four times, in 1965, 1977, 2003 and 2012 (Sandy Superstorm).

All predictions agree that there will be longer heat waves and higher temperatures. NYC will suffer more frequent heavy rains and storms, causing flooding more frequently. It is obvious that the city needs resilient building designs to ensure safety and best performance.

NYC currently uses gravity as an advantage to provide water supply without power. Furthermore, its gas supply is quite resistant compared to that of electricity. Due to the recent storms and blackouts, all procedures have been changed during the past six years in order to increase resilience against flooding.



New York City Extreme Weather Events. Source: National Oceanic and Atmospheric Administration & NYC Office of Emergency Management (7)

Due to Hurricane Sandy in October 2012, the states of New York and Massachusetts started to review all recovery strategies and opportunities to ensure that, in case of a similar event, all consequences were reduced to a small value. The procedure to follow was: To collect and analyse data on hazards and exposure, create scenarios of potential outcomes, monitor current conditions in response to hazards and risks, develop an inventory of buildings vulnerable to each risk, assess potential deaths/injuries and property loss and develop a checklist for vulnerability assessment.

Frequency and Severity of Natural Hazards in the State and Boston. Source Metropolitan Area Planning Council (MAPC) (8)

Hazard	Frequency	Severity
Flood	High	Serious to extensive
Dam Failure	Low	Extensive
Hurricane	Medium	Extensive to catastrophic
Severe storms	Medium	Serious
Tornados	Medium	Extensive to catastrophic
Winter storms	High	Serious
Earthquakes	Low	Catastrophic
Landslides	Low	Minor
Bushfires	Medium	Serious

On the other hand, the most common climate change hazards in Boston are floods from rain and coastal storms, extreme hot and cold temperatures and the indirect consequences of those hazards, such as power and services failure. All predictions show that sea level rising will increase the risk of flooding. Furthermore, wind storms will get windier and temperatures will get to even more extreme points. A recent study carried out by the Multihazard Mitigation Council found that each dollar invested in Boston for mitigation purposes created a benefit of $4.

As a sample, In November 2013 the Boston Planning & Development Agency adopted policy for all development projects subject to Boston Zoning Article 80 Small and Large Project Review, are to complete a checklist and provide any necessary responses regarding project resiliency, preparedness, and to mitigate any identified adverse impacts that might arise under future climate conditions. There are recent policies active such as BPDA Smart, Imagine Boston 2010, Resilient Boston and Climate Ready Boston.

3. THE ADAPTION CYCLE

Based on the extreme weather in the cities analysed above, there is a path to follow to adapt MEP designs to improve their resilience against climate change. The market and everybody involved with it must adapt and prepare for the future.

3.1. RISK AND IMPACT ASSESEMENT

The first step is to discuss and bring the topic into the project. The resilience of building will be facing many diverse climate phases on different moments. That is why the best approach is to develop a time frame to guide analysis of the issues. Such as:

PERIOD	2020	2040	2060	2080
Climate variables				
Business considerations				

It is also crucial to look at the Task Force on Climate-related Financial Disclosures (TCFD) recommendations to consider some of the risks that building services can create for the businesses inside the buildings if they are not adapted to climate change. It is essential that the time frame of the project considers all the risks the building will be exposed to in the present/future so that a practical and realistic design action can be undertaken.

The type of risk must be defined between low and extreme, defining what the meaning of each risk is. It is necessary to establish climate change projections and to make everybody in the project fully aware of the risks, and to designate roles and responsibilities within each team to asses each issue.

CONCEPT TO WATCH OUT FOR!

TCFD

Task Force on Climate-related Financial Disclosures (TCFD) was created by the Financial Stability Board (FSB) in 2015. The starting point was due to the crisis in 2000. The G20 created the FSB to identify and mitigate risks and threats that could make this crisis happen again. After the analysis, the FSB highlighted that one of the main topics to consider was climate change. The Board has released many documents related to this matter, with important recommendations for client businesses. It provides context, background and a general framework for climate-related financial disclosures, and is intended for a broad audience.

Building services engineers should discuss climate change topics with stakeholders, share their approach as well as spread the concept with other disciplines. Climate change affects the whole building, which means that all people involved in their design and building (architects, structural engineers, civil engineers, façade engineers…) have a common goal: creating a flexible design that can change its shape for the future. Who is going to oversee each task must be decided in order to split the responsibilities among the design team.

It is important to identify critical input at all stages of the building's lifecycle. The process must consider design stage, system installation, maintenance and operation. A resilient project should create a concept of cost-benefits and payback periods comparison within the initial climate change investment.

Resilience is imperative for businesses. As an example, a resilient building will maintain business continuity in an extreme event, which will minimise costs due disruption. Furthermore, passive designs are one of the main climate change fighters. Their use will reduce running costs due to the lower use of mechanical systems. A reduction in energy usage will minimise the exposure to big changes in energy prices for clients in the present and in the future.

3.2. MAIN MEP RISKS

All building designs must stop being considered as something tight and constant. They should start being more flexible and resilient. Buildings have to be able to adapt to climate change, and engineers should establish design strategies to palliate the impact of climate in building services.

Most contemporary buildings that perform well at the moment have been designed and built for the current climate; however, they will become inefficient in the following half century without the use of improved mechanical cooling and energy management.

The Intergovernmental Panel on Climate Change (IPCC) has published four greenhouse gas concentration scenarios. These options are known as Representative Concentration Pathways (RCPs). Four pathways have been created to describe four different futures. These future climates will be based on the greenhouse emissions that we produce in the following years.

SCENARIO (9)		GLOBAL WARMING MEAN AND LIKELY RANGE ˚C
RCP 2.6	Emissions peak 2010-2020, then decline substantially	1.0˚C (0.3 to 1.7)
RCP 4.5	Emissions in RCP 4.5 peak around 2040, then decline	1.8˚C (1.1 to 2.6)
RCP 6.0	Emissions peak around 2080, then decline	2.2˚C (1.4 to 3.1)
RCP 8.5	Emissions continue to rise throughout the 21st century	2.2˚C (1.4 to 3.1)

These changes will affect buildings and building services. All scenarios will be different in every country, as climate is different based on many characteristics, but the key of being resilient and flexible is to have a minute thought to all of them to consider the risks that the scenarios can lead to.

It is a fact that climatic data is a key concept for building services strategy. All climatic concepts are related to building services designs:

CLIMATIC ASPECT	DESIGN ASPECT
▪ Solar path and position ▪ Temperature and solar radiation ▪ Sunshine duration and cloudiness	SOLAR DESIGN STRATEGIES
▪ Temperature, humidity and solar values ▪ Wind and pressure ▪ Extremes and average of climate	HVAC SYSTEM DESIGN
▪ HVAC Design (based on climate) ▪ Design days/week ▪ Typical year and multi-year data.	BUILDING ENERGY

As the chart shows, climate change is linked to building performance. Newly built and refurbished projects must consider at least one RCP to ensure the best performance and react to extreme situations.

The following chapters will show what risks existing building services will face in the coming years due to climate change. All of them must be considered or raised at early stages so that they can be discussed and the best solutions and strategies found.

3.2.1. HEATING AND COOLING RISKS

Warmer winters may have a generally positive effect on building performance. However, during the summer season, buildings will have the greatest impact due to the rise in temperature. Global warming will affect their performance and the users' comfort. Building facilities will face many risks due to this climate effect. The main risks to consider are:

Mechanical

Heating island effect will rise for three reasons: • The number of buildings being built is increasing • Outside temperature will grow every year • In some areas, split units will dump heat to outside spaces, increasing the heat island effect	Cooling requirement will increase. There will be an increment of demand for air conditioning, which will be directly connected with an increase in energy prices. HVAC systems may even experience overload, affecting thermal comfort for building occupants	The cooling capacity of ventilated air will fall due to high temperatures. In heat waves, natural ventilation could even rise internal temperatures
Heat recovery designs may become less efficient. The reduction of ventilation heat loss (one of the benefits of this system) will become less required. Due to the increase of winter temperatures, there will be a point where, in some areas, the heat reclaimed will not be cost-effective	Overheating inside buildings	There will be more microclimates on roofs. A microclimate is when local temperatures get much higher than the ambient. This can be caused by volumes of air stacked next to hot surfaces
Air cool condensers work at maximum ambient temperatures of 45˚C. Due to microclimates and heat waves, this temperature can be reached, and the safety cut-offs will be activated. That will reduce cooling capacity	Energy-saving measures, such as night cooling, will be less reliable	Equipment, such as air compressors or lifts, could stop working during extreme weather due to their in-built safety features (such as HP, LP trips). Building and business performance will be affected

Electrical

High energy demand could lead to not enough capability being available on the main energy supply	Variation in temperature causes condensation inside electrical switchboards, leading to failure	Electrical equipment operates at a maximum temperature of 50˚C. Electrical equipment will have temperature issues as cooling equipment will work at higher levels, plus the direct solar radiation will elevate switchboard enclosure temperatures. This will reduce the service life and the resilience of the system

Public health

	Consumption of domestic water will increase. Furthermore, due to the extreme heat events, water consumption and water availability will become unpredictable	

Equipment - General

Radiant heating will affect the electronic sensors and protection devices in roof equipment due to high temperatures captured by metal surfaces. This will force the equipment into shut down and will stop producing cooling and heating	Increase of maintenance and operating tasks due to extra work of cooling system	MEP equipment at roof level will suffer solar exposure, which will lead to faster material degradation. This will occur for two reasons: high surface temperatures and increase in the level of UV radiation, which will increase the rate of photo-oxidation. Maintenance costs will increase

Clients

	For landlords and clients, it is important to realise that grid electricity prices will be higher in the future due to availability of resources and consumption requirements due to climate change	

CONCEPT TO WATCH OUT FOR!

HEAT ISLAND EFFECT

This effect occurs when the built-up areas are hotter than their surroundings. This effect happens when there is a big amount of local heat production and reduced green areas. The heat is absorbed by buildings and landscaping during daytime and is released to the urban area during the night, making a 24h heat effect. Temperatures in urban areas can easily be 3-5 ˚C above outlying rural areas. During long heat waves, this difference can rise to 10 ˚C.

3.2.2. RAIN AND FLOODING RISKS

Peak rainfall is expected to increase compared to current levels. The pattern, amount and intensity of rainfall will be affected due to the increase in temperature. This will happen due to two main reasons:

First, warmer air can heat the water on the earth surface faster. This water evaporates as water vapour. All this vapour rises into the air and condenses when it cools down, forming clouds. Secondly, due to climate change, the air will be warmer, making it able to hold more moisture than cool air does. This leads to a great amount of moisture, which causes heavier rain.

Combining both effects, the rainfall will be more intense, increasing the risk of flooding. This effect is directly related to building services, as buildings will have to face the following risks:

Neighbourhood storm water management systems will be overwhelmed	Storm water damage will increase	It will rain more heavily. This will cause flooding due to the rain itself and due to rivers and lakes overflowing
Local water table and groundwater level changes could mean ground floor plant rooms could be at risk of flooding	Contamination and disease from sewer water due to flooding	Critical equipment, such as generators and switchboards, could be damaged due to water
Façade and roof drainage systems may become overloaded, resulting in water damage	An increase in peak rainfall will translate into less constant raining. That may result in drier summers. If there is a lack of humidity, droughts and ground shrinkage will take place, and any system working with the ground (ground source heat pumps, electrical earth rods)	Rising sea levels due to global warming will cause flooding by reducing the ability of rivers to drain floodwaters away

CONCEPT TO WATCH OUT FOR!

GLOBAL WARMING RULE OF THUMB

+1˚C = 5%

One-degree increase in temperature equals a five percent increase in rainfall intensity

3.2.3. AIR RISKS

Climate change is affecting the air pattern. Ventilation is a key purpose of building services, and it will be affected in quality and performance. For this reason, the following risks must be considered when designing a resilient system:

Air quality

Bad air quality combined with heat waves will increase death due to respiratory problems	Ground-level ozone concentrations may rise due to higher temperatures, increasing risks to users' health. It will increase air stagnation and there will be less pollution dispersal	General air quality outside the building will be reduced due to an increase in pollutants. For example dust quantities are likely to increase

Air performance

High wind velocities can damage exposed equipment in the roof or the façade, such as PV, fans, solar water heaters, etc.	Wind can damage electrical and data assets located outside the building, such as lighting rods, antennas, etc.	Temperatures will rise, so natural ventilation will be much less effective for cooling indoor air

3.2.4. FIRE RISKS

In some areas, there will risks of bushfire. The main cause of fire is the combination of a big amount of vegetation (fuel) and hot and dry climate. Climate change leads to hotter temperatures and less constant rain, which will result in higher risk of bushfire. The risks that MEP designs will have to face are:

Severe damage to external elements on the roof and the façade	Smoke and particulate pollution transfer from the outside to the inside	Some of the buildings are not well designed to create an alarm to communicate outside fires
	In case of big bushfire, some of the big buildings will act as refuge point. This will increase the occupancy levels to above maximum capacity, so the MEP capacity will not be enough in that space. This is critical because this is an emergency in which users require optimized fresh air and comfort temperature	

3.2.5. HAIL/SNOW RISKS

In some areas, the risk of hail will increase by more than 20%. Hail can affect the building services very badly. The main risks to consider due to climate change are:

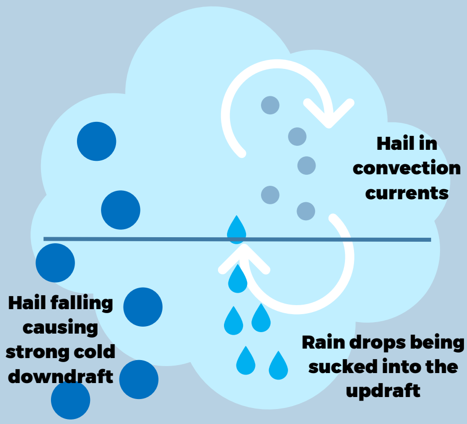
Severe damage to external elements on the roof and the façade	PV will lose efficiency and even stop working	Vent pipes damaged due to impact
Metal slats of condenser units can get damaged. It will affect the airflow by reducing their capacity, which will cause the equipment to work harder or even stop producing the load demanded	Dents on fan motor and blades of exterior units and pumps	Ductwork can get damaged, creating air turbulence and affecting HVAC performance
Pipework damage that can lead into refrigerant leaks, loss of performance and even loss of cooling systems	Low temperatures can also freeze pipes containing water and safety controls located outside	

CONCEPT TO WATCH OUT FOR!

HAIL AND CLIMATE CHANGE

Due to climate change, most cool and dry areas are expected to become warmer and moister. This will cause stronger updrafts and greater moisture availability. (10)

As a consequence, both average hail diameter and frequency of large hail occurrence are expected to increase, significantly affecting building services.



3.3. MEP RECOMMENDATIONS

Considering all risks mentioned above, it is a fact that resilience is a key factor to achieve best building performance in present and future designs. In order to do that, the following recommendations provide guidance for an adaptive MEP system.

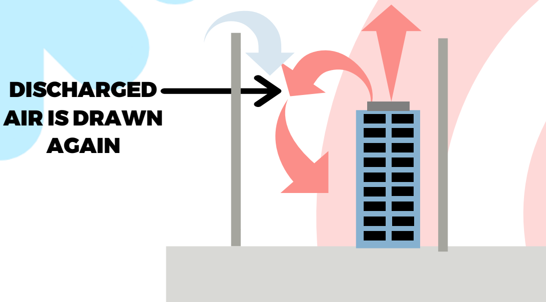
3.3.1. HEATING AND COOLING ADAPTATION MEASURES

For a resilient design, it is important to combine active and passive strategies. This means that some of the measures to take are directly connected to building services. However, designs must highlight all passive options as well. It is necessary for all building facilities designs to consider every type of aspect that will affect their performance.

Direct/active building services measures:

Even buildings with good passive designs will require more active cooling due to global warming. The best considerations for a resilient building are:

- Adapt weather data further and work with scenarios based on the latest databases i.e., IPCC.
- Search for free/slab cooling opportunities.
- Get higher COP and efficiency mechanical elements, such as chillers and cooling towers. It will reduce the amount of energy required to offset the need for extra cooling during heat waves.
- Install enthalpy wheel energy recovery systems on air handling units. This will reduce energy used to condition outside air.
- Propose HVAC designs that allow for expansion in the future if cooling capacity is no longer sufficient. Consider allocation of future plant space for additional cooling plants if required.
- Check the manufacturers' maximum operating temperature.
- Specify HVAC equipment to keep working during an extreme weather event if required. In-built safety features (HP, LP trips) will have to be redesigned to ensure they do not activate during this period.
- Propose and encourage installation of green roofs and green walls on buildings.
- Regulate natural and mechanical ventilation timings and combine them with numerous materials with high thermal mass properties. This will reduce energy consumption and balance the building when temperatures change drastically outside due to the weather.
- Use of ground cooling. Ground water cooling should also be considered. Even in a heat wave, ground floor temperature remains constant. The earth is at a constant temperature of 10-15˚C. By drawing external air deep into ground, it can get temperate, so cooling/heating energy use is reduced.
- Check extreme performance when modelling, such as 28˚C for less than 1% of the time and exceeding 25˚C for less than 5% of the time.
- Ensure there are no obstacles to the outdoor unit discharge air. Avoid inefficient air recirculation that could rise temperatures in a heat wave.



Air recirculation caused by an adjacent screening wall. (11)

- Provisions for increased frequency and duration of electrical power outages should be considered due to the increased demands.
- Electrical switchboards should be maintained below maximum ambient temperatures of 50˚C for reliable operation.
- It is important to avoid condensation on switchboards when extreme variation temperatures occur. Specify anti-condensation heaters to ensure correct performance.

- Critical electrical equipment, such as electrical switchboards, should be located indoors or shielded from direct solar radiation. If it is not possible to achieve that, it is recommended to design integral cooling circuits for them.

CONCEPT TO WATCH OUT FOR!

REDUNDANCY

In the building services field, redundancy is defined by using terminology like: N, N+1, N+2, 2N, where N is the number of equipment working. By adding redundancy, resilience increases because the single points of failure decrease. In all systems, redundancy can be achieved by using duty/standby strategies. Redundancy can be used to complement the main equipment, such as by adding extra pumps or more compressors to individual equipment.

Indirect/passive building services measures:

Passive design strategies offer real benefits for building services. Having cooling systems providing thermal comfort does not mean that the building must use full air conditioning systems. A passive approach will minimise the energy used whilst maintaining comfort. Most importantly, these strategies can maintain and keep constant the performance of the building without being affected by the outside climate, which s increases resilience. A lot of the following considerations are currently being used in many countries, such as in Southern Europe, Hong Kong and Australia. Some of the main recommendations are:

- Redesign and optimise U-values and G-Values. This will reduce the heat transfer on the building envelope and isolated indoor environment from the outdoor climate.
- Collaborate and recommend update of windows with improved U-values and better thermally broken frames.
- Specify shading devices, such as blinds and external shading.
- Collaborate and encourage airtight designs in order to control ventilation and reduce infiltration factors. Note that, in this case, inside temperature should be considered. It could increase heat gains in summer if the inside heat gets trapped in a well-insulated building. Cover all MEP heat transfer openings, such as piping, ductworks, electrical elements, etc. Create a barrier to seal the building envelope and reduce air infiltration between the outside and the inside.

CONCEPT TO WATCH OUT FOR!

ENVELOPE VALUES

- ✓ **U-value: This value describes the heat transfer capacity of the element. The value shows the maximum amount of watts transmitted in one square metre. Lower U-values result in better performance.**
- ✓ **G-Value: It is a measure of how much solar heat is allowed in through a glass area of the building. A low G-value means that the glass allows a low percentage of the solar heat through.**
- ✓ **Infiltration: the quality of sealing of the envelope. Avoiding leakages through building fabric and windows will reduce uncontrolled air exchange between the outside and the inside. This is a key factor during events of extreme temperature and high winds.**
- ✓ **Solar Heat Gain Coefficient (SHGC): this parameter qualifies how effectively the window system controls solar heat loads from the outside to the inside the building. It is a value between 0 and 1. Effective shading designs will help block solar heating during heat waves.**

- Additional roof insulation. Collaborate with architects to increase the roof layer. The result will reduce cooling and heating loads on more extreme weather by reducing the amount of energy used by HVAC equipment.
- Specify lighter colours in roofs. Avoid exterior equipment with dark colours.
- Collaborate with structure engineers and architects to implement the usage of materials with high thermal mass that can soak up unwanted heat during the day and release it during the night.

CONCEPT TO WATCH OUT FOR!

THERMAL MASS

When designing thermal mass strategies, consider:

- ✓ **Large surface area is more important than thickness (> 150 mm depth is not hugely beneficial)**
- ✓ **Combined with good night-time ventilation**
- ✓ **High thermal mass materials are concrete, brick and stone. The best thermal mass material with the lowest embodied carbon is water.**
- ✓ **Prioritise retrofitting externally solid walled properties with eternal insulation. It will avoid difficult thermal bridging.**
- ✓ **Thermal mass may delay the need to upgrade mechanical cooling systems by 30 years.**

- Consider improving envelope strategies in all refurbishment projects.
- Specify plants and green areas.

CONCEPT TO WATCH OUT FOR!

PLANTS AND BUILDING SERVICES

Plants are a low-cost cooling, shading and attenuating system. It is recommended to develop the concept of plants and building services. Buildings will perform differently based on the presence of plants, as plants can affect the buildings in many ways. They can increase U-values by adding green living walls or green roofs. This will reduce the need for mechanical air conditioning. Plants can act as noise attenuators between MEP equipment and the outside. Furthermore, they can clean outside and inside air, which will improve air quality without needing extra filtration systems. They can be used against heat island effect

3.3.2. RAIN AND FLOODING ADAPTATION MEASURES

To ensure that building services respond correctly to heavy rain and flooding, all of the following concepts should be considered:

- Locate wiring and electrics higher up the building.
- Avoid plants in basements if there is a risk of flood in the future. Raise plants above existing and predicted flood levels.
- Raising equipment above floor level on plinths or mounting frames and the use of bunding is also recommended.
- Avoid locating water treatment, fuel tanks and expansion vessels in areas that could be flooded. All chemicals in building services should be restrained to prevent flotation under flooding.

- Electrical equipment must not be located below pipework. Reduce joints and points of failure to ensure system integrity is not affected under a big movement, such as typhoons or earthquakes.
- If there are water features, such as fountains or swimming pools, avoid locating critical equipment below them.
- Do not assume that drainage systems will be 100% reliable. If plantrooms cannot be above flooding levels, ensure enough capacity with redundancy and standby power for drainage system.
- A design based on +30% rainfall intensity must be included.
- If your project is upgrading existing schemes, ensure it will cope with heavier rain and flooding, and the ability of drains to cope with higher intensities.
- Liaise at early stages with ground engineers to discuss any risks of getting ground droughts and ground shrinkage in order to maintain efficiency with ground building services.
- In case of flooding, consider interdependencies of systems across the building as backups and isolation.
- Installation of containment or water leak detection system.
- Design landscaping choices to help manage a heavy storm water runoff for your site and area.
- Brief the clients on the risks of power failure on a climate change prospect.
- Specify sewage valves to prevent back-flow into basements.

3.3.3. AIR ADAPTATION MEASURES

A resilient ventilation scheme is important for the best performance in climate change scenarios. To design systems that adapt to changes in air patterns, the following recommendations should be considered:

- Due to the increase in wind speeds, it is critical to improve fixings located outside the building, such as PV panels, cooling towers, drainage pipework, etc. Contact manufacturers and façade engineers to find out about the physical capacity against winds. Explore what values have been used and what can be improved.
- Carry out risk assessments on how heavy winds could affect current designs.
- List all consequences of heavy winds and how they can affect building performance. For example, solar panels pulled out, cooling towers being moved, outside pipework hit by objects blown by the wind.
- Consider tunnel effect with higher wind speeds and what consequences it could have in your designs (even if there is no risk now).

CONCEPT TO WATCH OUT FOR!

TUNNEL EFFECT

This effect occurs when the air is compressed on the windy side of the buildings so that its speed increases between the streets. It can be useful when designing wind turbines. However, considering wind velocities due to climate change, it can become a problem in cities.

- Consider the use of wind energy in soft medium areas. They may change to windier areas in the following years.

3.3.4. FIRE ADAPTATION MEASURES

Due to climate change, the risk of bush fire and ember attacks are increased. To adapt to this and have a resilient system against fire, the following steps should be followed:

- Design BMS systems operation of HVAC on full recirculation in case of bushfire. The concept is to have the building recirculate the air when there is smoke surrounding the building.
- Analyse the risk of bushfire even if your building is currently located outside the bushfire zones. Buildings can still be affected depending on factors such as prevailing winds.
- Specify ember guards in ventilation openings.
- Design gas and water pipes to be metal when they run above ground.

- Program BMS systems to override the minimum outside air if smoke is detected outside the building.
- If there is a risk of fire, shut off supply and return air dampers to critical areas to maintain room conditions.
- Specify a low-leakage spring return type damper where the systems are important.

3.3.5. HAIL/SNOW ADAPTATION MEASURES

Hail can cause damage to external equipment through mechanical impact. Any building services located outside risk suffering disruption. To increase resilience against hail, the following recommendations shall be taken into account:

- Shelter equipment located outside the building with special hail protection.
- Consider the risk of weight. Excessive ice collected on equipment can affect its performance. Specify a proper maintenance and surface protection regime to avoid excess of weight.
- Protect box gutters to avoid blockage of water flow.
- Shelter equipment from the cold by using thermal insulation and trace heating.
- Hail guards should be installed on exposed equipment in the roof. Some of the equipment, such as cooling towers, have drift eliminators made of plastic. This material can be damaged easily, so they need to be protected.

3.3.6. ENERGY ADAPTATION MEASURES

The future market will be dominated by electricity. For this reason, current designs should be looking at those requirements. This means that, in the event of a climate-related disruption, the ability to stay online and/or restore the electricity supply quickly is now even more important for high-resilience performance.

Depending on the type of project, “stand-by” systems or “plug and play” systems can be used.

Critical systems are designed with redundancy or a provision of stand by features. This can be achieved with standby generators, UPS and batteries to provide energy in case of main systems ceasing to work due to extreme events. However, in some cases, providing stand-by systems and redundant capacity is a big capital cost.

On the other hand, plug and play systems can provide flexibility in an extreme power disruption event. Mechanically, to use this system it is important to provide enough connection points for back up cooling systems. Furthermore, it is recommended to provide enough access to ceiling and risers for connecting temporary cooling units and exterior hook-ups to allow easy connection to portable generators.

Increment the use of individual energy sources, such as CHP and microgrids. By using these systems, energy can be used, exchanged and stored to provide resilience and capacity for the building. In a blackout event, cogeneration and solar power systems should be designed to run together.

Regarding gas supply, if there is a failure in the main gas system, it would be advisable to add a secondary fuel source, such as diesel, to provide heating to the building.

Provide connection points to sprinkler or hydrant water storage tanks so that this static water supply can be used as a heat exchanger.

3.3.7. EXTREME EVENTS ADAPTATION MEASURES

Building energy system must be designed considering worst-case scenarios, such as extreme events. To do that, provisions and temporary equipment must be considered to keep energy performance. This strategy works by adding spare connections to temporary units in case that units on site fail. To achieve this, provide transfer switches and link boxes for generators and spare connections in heating and cooling systems to connect to temporary skid-mounted units.

Furthermore, all designs must include seismic protection to ensure building services will assist and answer correctly against a blast. Specific blast valves for air ventilation system intakes must be brought into the design if required.

On this area, building management systems is a key factor for a strong resilience. The building can respond easily with the correct orders from the BMS.

If there is a seismic movement, such as an earthquake or a big impact due to wind or typhoons throwing objects, it is recommended to reduce the indirect consequences. Due to this movements, fuel or gas pipes can be damaged and can create extra explosions. To avoid this risk, automatic actuators with backpressure-sensing reset functions should be specified.

3.3.8. REFUGE IN MULTIHAZARD EVENTS

During the past few years, there has been a trend of associating "extreme weather events" with "safe evacuation". However, due to the recent increase of weather effects, designs must change and adapt to new requirements. Instead of safe evacuation, some buildings must be able to protect their occupants and act as a temporary "resilient refuge."

Depending on the outside characteristics and the location of the building, building services will have to respond in different levels depending on the risks and hazards. Design teams should work together with stakeholders to establish what level of resiliency the building will require against extreme events.

Performance must be switched to a minimum to provide enough to survive. Basic level of lighting, power and air conditioning with minimum levels of fresh air.

CONCEPT TO WATCH OUT FOR!

REFUGE "MODE" DESIGN CRITERIA

- ✓ **Fresh air below design values, i.e., <8 L/s per person.**
- ✓ **Temperatures between 15˚ and 30 ˚C.**
- ✓ **Keep refuge spaces isolated from unconditioned spaces.**
- ✓ **Lighting around 30 lux.**
- ✓ **Basic toilet facilities, with restricted flushing.**
- ✓ **Program BMS to minimum services (stop services in non-essentials areas, move temperature set points, modulate mechanical equipment).**

3.4. MONITORING, MAINTENANCE AND ACCESS

Inspections and preventive maintenance are required to ensure that all the equipment responds as planned during an extreme climate event. To do that, accessibility is a key factor to make maintenance efficient.

This strategy should be planned at early stages. The designers and the maintenance companies must work together to create clever designs that works in case of an extreme event. Access should be considered inside and outside of the building.

It is important to have a close inspection after a significant climate event, such as extreme winds, flooding and earthquakes. Climate change can create many extreme situations where temporary solutions must be considered. The design must consider the provision of generators, cooling or heating equipment, fuel or water through driveways and vehicular access. To access the affected areas, provisional or removable external access should be considered to access plant key points. There should be a provision of beams and davits for installing or replacing heavy equipment.

Engineers must provide a good set of information, such as manuals and drawings, to maintain resilience in the building against climate change as well as define and differentiate essential services. Emergency points must be maintained to ensure that they remain operative.

Furthermore, training is critical for emergency and extreme conditions. All maintenance staff and building members should be trained for climate events to provide the best building performance for the sake of the building and its occupants.

4. CONCLUSIONS

Climate change is a reality. Our designs cannot rely on what is happening in the present: they have to be ready for the future. Building services must be resilient and adapt to present and future scenarios in order to provide the best performance.

Global warming is happening, producing warmer temperatures that will require extra amounts of energy that existing designs will not be able to deliver. Building must combine passive strategies (such as a better envelope) and active strategies (such as free cooling or ground floor systems).

Peak rainfall is expected to increase compared to what it is today. This is correlated with higher temperatures. All of this will increase the risk of flooding. Basements full of water with critical equipment in danger will lead into bad building performance and will stop business due to lack of power. It is important to not rely on drainage equipment and to think ahead by locating critical systems above levels at risk of flooding.

Due to higher and dryer temperatures, bushfires will increase. Buildings must respond perfectly to these events to avoid or reduce damage as much as possible. HVAC systems must detect smoke from outside and keep inside areas isolated. Building services must be able to resist fire long enough to increase building resilience.

Hail risks will rise and cause severe damage to external elements on the roof and the façade. It will reduce the performance of services. All equipment at risk must be sheltered against hail with guards. Furthermore, openings, such as louvres, outlets, and even the equipment itself, can be affected due to the weight of the ice. Maintenance and quick response are key to keeping services running normally during extreme cold temperatures.

Due to the recent changes in climate mentioned above, building users will need the building to act as protection against extreme multihazard events. Building services should provide enough capacity to the building to act as a "resilient refuge". Design criteria must be carried out to provide survival features to the users until it is safe to leave the building.

Design for today with tomorrow in mind

5. APPENDIX

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5.2. WSP AND FUTURE READY

WSP is a globally recognised professional services firm employing approximately 48,000 people.

Through Future Ready, WSP brings clarity and vision to complex challenges. We see the future more clearly through key trends in climate change to work with our clients to advise on solutions that are ready for our future world as well as today. Future Ready delivers peace of mind, lower lifecycle costs and resilience.

With the Future Ready programme, our experts are able to help our clients prepare for future realities of more severe weather events, amongst many others.

We work to shape an environmental, sustainable vision and strategy which will give clear market stand-out, address the areas of greatest impact and make a positive bottom-line impact.

Are you Future Ready?

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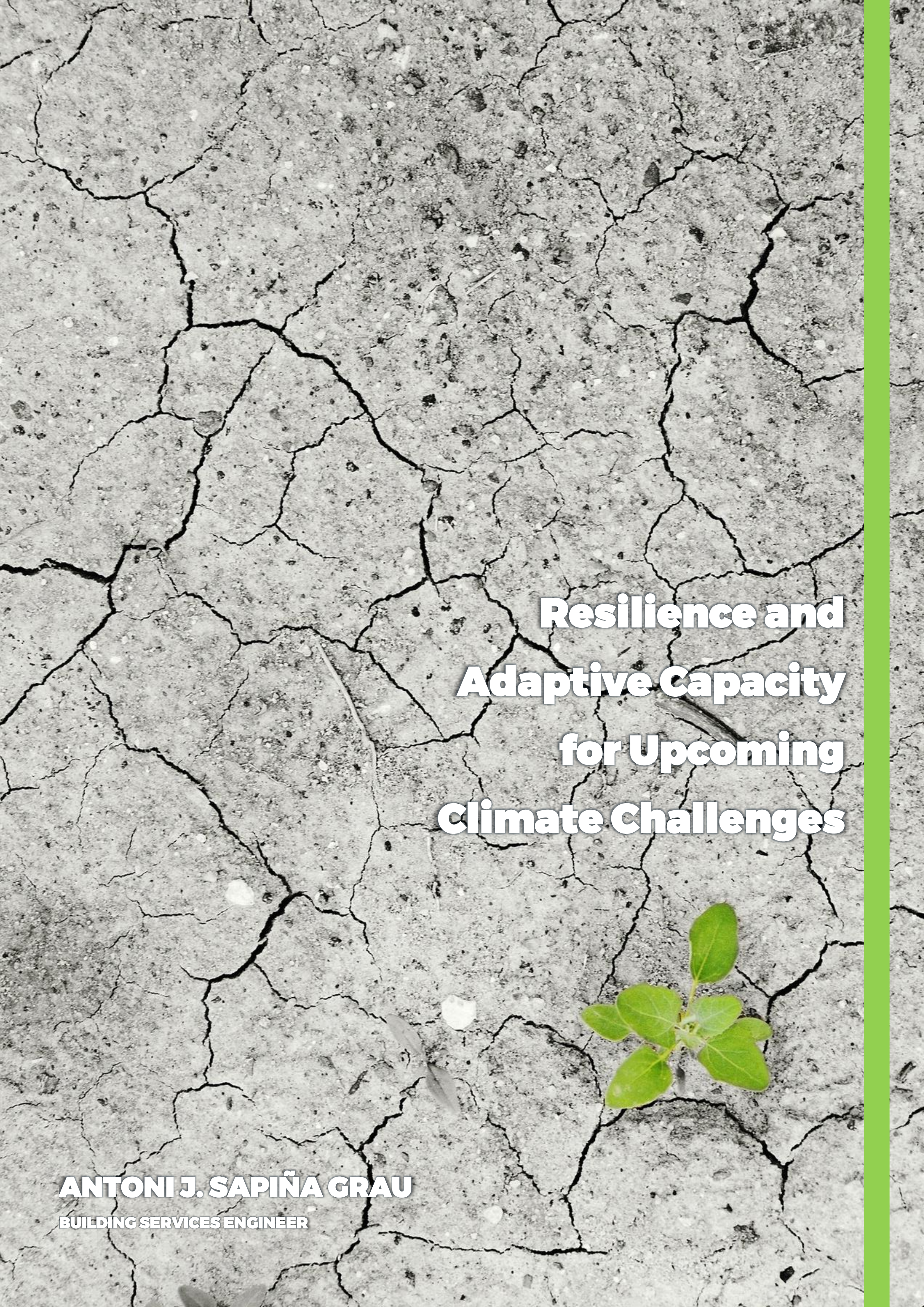

Resilience and Adaptive Capacity for Upcoming Climate Challenges

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